POWER PLANT ENGINEERING

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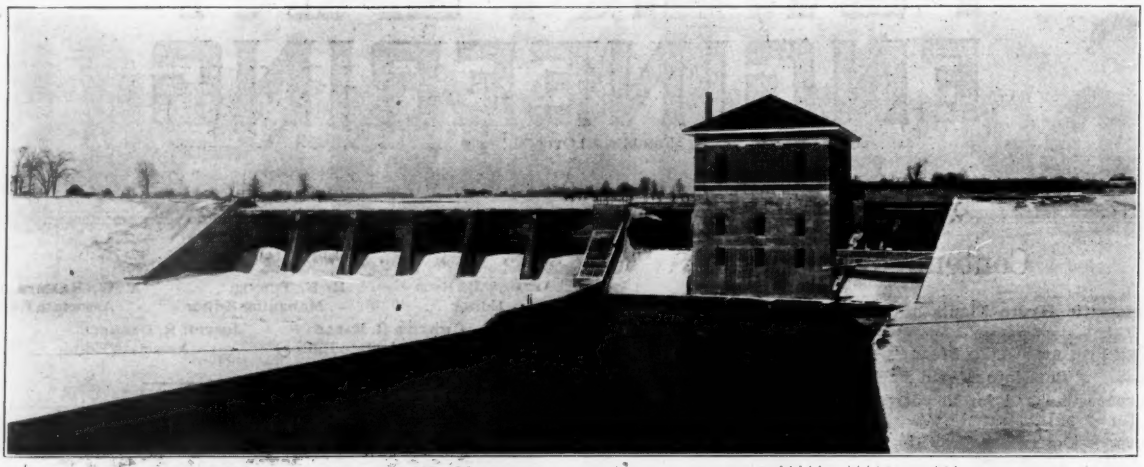
A Governor with Brains

OF COURSE, there are governors with brains and governors without brains—no, we're not insinuating anything. We're talking about the water wheel governor shown above, not about the governor of Texafornia or the governor of Montavania. But as we stood beside this water wheel governor one day and watched it operate, as it was controlled over a telephone line from a point several miles away, it almost seemed as if this governor had a brain.

For example, when the signal comes over the control wire, closing the master relay that starts the exciter, connects it to the main generator and then starts to open the governor by an electric motor, the governor will refuse to budge unless its oil pressure is high enough. When the machine is running and carrying load, if a bearing should get too warm or if any of the windings should get overheated, the governor will promptly shut down the unit and ring an alarm to call the operator. In other words, if all conditions are not just right, the governor will not start the turbine or, if in operation, will not allow it to continue.

The brain of the above governor is, of course, the system of electrical relays that control it, and the operation of this system is unusually fascinating. The governor shown is installed at the Paper Mill hydro plant of the Detroit Edison Co., one of a group of six located on the Huron River in southern Michigan. A detailed description of these plants, together with a discussion of the interesting features of the governor with brains, will be found in this issue.



Automatic Hydro Plants of the Detroit Edison Co.

SIX AUTOMATIC AND REMOTE-CONTROLLED HYDRO PLANTS ON HURON RIVER IN MICHIGAN, WITH TOTAL CAPACITY OF 7800 KW., SERVE ANN ARBOR AND YPSILANTI DISTRICT

DURING the past few years, automatic operation of hydro-electric plants and substations has been creating great interest. A typical example of the successful use of such automatic control is the group of hydro-electric plants on the Huron River in Southern Michigan near Ann Arbor and Ypsilanti, operated by the Detroit Edison Co. Reference to the layout of the Detroit Edison Co.'s system, as given in Fig. 1, will show the location of these plants with respect to the rest of the transmission system. They were at one time used as a sort of voltage regulator on the main system, but that purpose is now subordinate. They are now used at certain times for power factor correction. They serve the cities of Ann Arbor, Ypsilanti and surrounding towns through 23,000-v. transmission lines, being tied into the main 120,000-v. system at the Superior substation, as will be explained.

In this group of hydro-plants, the installations vary in size from 800 kw. at the Paper Mill plant to 2500 kw. at the French Landing plant, which has only recently been completed. Following is a list of the plants in order down the river with the heads utilized at each.

Plant	No. Units	Total Capacity	Head
Barton	2	1500 kw.	26 ft.
Argo	2	900 kw.	14 ft.
Geddes	2	900 kw.	17 ft.
Superior	3	1250 kw.	17 ft.
Paper Mill	2	800 kw.	14 ft.
French Landing	2	2500 kw.	32 ft.
	13	7850 kw.	120 ft.

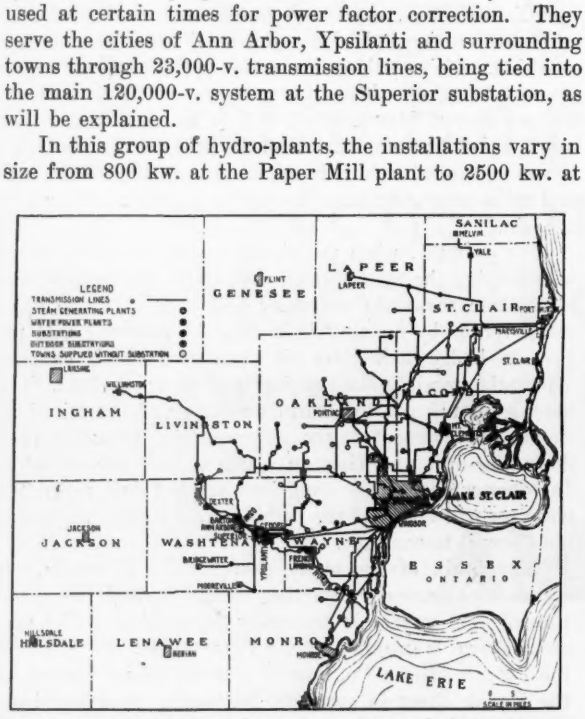


FIG. 1. HYDRO PLANTS NEAR ANN ARBOR AND YPSILANTI SERVE LOCAL 23,000-V. LINES AND TIE INTO SYSTEM AT SUPERIOR

Reference to the various illustrations will show the arrangement of the generating units in the various plants. After describing these units briefly, the automatic control system and the principal features of its operation at Barton plant will be discussed, since the automatic and remote control features here are typical of those at the other plants.

All these plants generate at 2300 v. except French Landing and Paper Mill, which generate at 4600 v. Power is stepped up at each plant to 23,000 v. to feed into the 23,000-v. local service system. In case the local load cannot be carried by the hydro plants, the 23,000-v. system takes power from the 120,000-v. lines which are fed by the great steam plants at Delray and Conner's Creek in Detroit, Trenton Channel below Detroit and Marysville at Port Huron. For this reason, all the hydro plants are operated for maximum efficiency with the amount of water available at a given time. Connection with this line is made at a 120,000/23,000-v. step-down substation at Superior, which thus becomes the key plant and the primary control station of the hydro system. As the result of being struck by lightning, the switching station at Superior was recently replaced by a temporary one erected in 26 hr., as described in the Sept. 15 issue of Power Plant Engineering.

Control of the plants at Geddes, Paper Mill and French Landing is effected over control circuits by the operator at Superior. These plants are, in reality, remote controlled rather than automatic. The Barton plant, however, is controlled from Argo by means of the automatic

dial telephone supervisory control to be described later. The above arrangement permits using only 3 operators, whereas 12 were necessary with manual control. One man looks after Geddes and Paper Mill plants, one is at Barton and one at French Landing, their duties being mostly to supervise and maintain the equipment. This eliminates the 3 shifts formerly necessary at these plants and it can be seen that the saving due to this item alone is considerable. At Argo and Superior, it will be necessary, of course, to retain 3 men in each plant, one for each shift.

At the newest plant in the system, French Landing, which has just been put in operation, two Allis-Chalmers Mfg. Co. water wheel generators are installed, rated at 1200 and 2400 kv.a., respectively, or about 2500 kw. at 0.7 power factor. These have Francis type runners, the 1200-kv.a. unit operating at 164 r.p.m., and the 2400-kv.a. unit at 120 r.p.m. Exciters rated at 27 kw. and 45 kw. at 110 v. are mounted on the generators, as shown in Fig. 3. The dam and power house at French Landing are shown in the head piece.

At the Paper Mill plant, which is leased from the Peninsular Paper Co. in Ypsilanti, two Allis-Chalmers Mfg. Co. Francis type water wheels drive two Allis-Chalmers generators at 100 r.p.m. with a total capacity of 800-kw. One exciter, rated at 20 kw. at 125 v., is belt driven from one of the main shafts; a second exciter, rated at 45 kw. at 125 v., in the form of an Allis-Chalmers motor-generator set, is provided.

Superior plant has three main generating units. One is a Leffel water wheel driving a 450-kv.a. General Electric Co. generator at 100 r.p.m. The exciter for this is a G. E. Co. motor-generator set, a 2300-v. a.c. motor driving a 22-kw., 110-v., d.c. generator. A second Allis-Chalmers water wheel drives a 250-kw. G.E. generator at 120 r.p.m., the exciter for this being a direct-connected 15-kw., 120-v. Allis-Chalmers generator. The third and newest unit is an Allis-Chalmers water wheel and generator of 625 kv.a. capacity. The exciter is a G.E. Co., 40-kw., motor-generator set, the motor drive being at 2300 v. The total capacity of this plant is about 1250 kw.

Geddes Plant Contains Propeller Type Runners

Two generating units of 450-kw. each at the Geddes plant are driven at 200 r.p.m. by Nagler high speed propeller type runners, these units being supplied by Allis-Chalmers Mfg. Co. One of these runners has 4 blades and discharges into a draft tube. The other, which was formerly a 3-blade runner, discharging into a White hydraucone, has been replaced by an adjustable 4-blade runner, which has been found to give higher efficiencies. Exciters are mounted directly on the main generator shafts, above the generators, and are rated at 17 kw. at 125 v.

FIG. 3. AT FRENCH LANDING, RECENTLY ADDED TO THE SYSTEM, TWO UNITS WITH A TOTAL CAPACITY OF 2500 KW. ARE INSTALLED WITH DIRECT-CONNECTED EXCITERS

At Argo plant, two 450-kw. General Electric generators are driven at 100 r.p.m. by Allis-Chalmers Francis type water wheels; a G.E. Co. motor-generator set, rated at 35 kw. at 125 v. and driven by a 220-v. a.c. motor, furnishes excitation for the a.c. machine. One of the main generators here is a 2300-v. a.c. machine; the other is a 650-v. d.c. generator, which supplies power to the local lines of the Detroit United Railways. Only one turbine governor is installed here, arranged to use on either machine or on both. The d.c. generating unit is operated at full gate opening when water is available and motor generator sets as shown in Fig. 2 are run on the line with it in such a way that power not used on the electric railway lines goes back through the motor-generator set into the a.c. system.

Figure 5 shows some of the details of equipment at the Barton plant, which is controlled from Argo, as will be

FIG. 2. AT ARGO ONE UNIT GENERATES D.C. FOR RAILWAY WORK, UNUSED POWER FEEDING BACK INTO THE A.C. SYSTEM THROUGH THE M.-G. SETS IN THE BACKGROUND

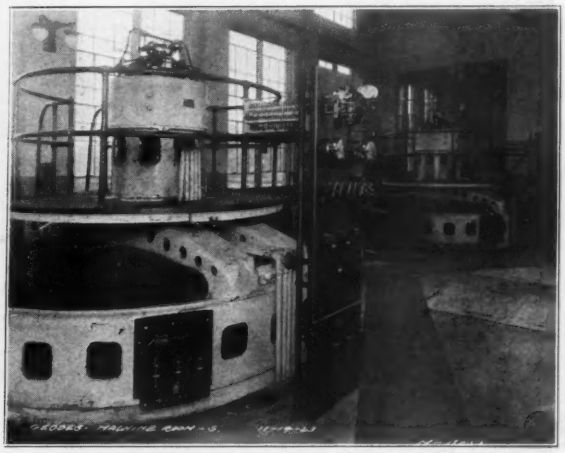
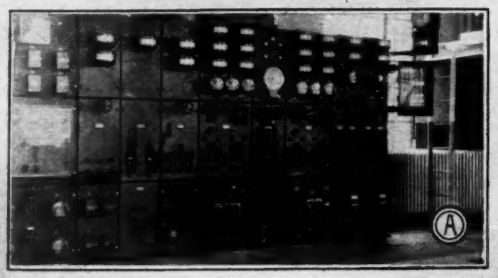


FIG. 4. TWO 450-KW. UNITS AT GEDDES, WITH DIRECT-CONNECTED EXCITERS, ARE DRIVEN BY PROPELLER TYPE RUNNERS



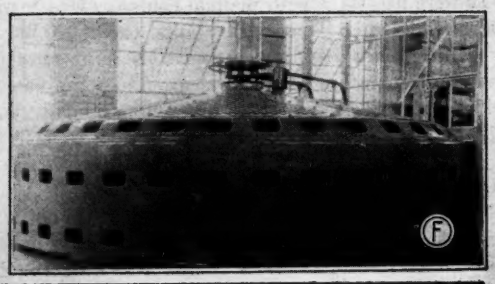
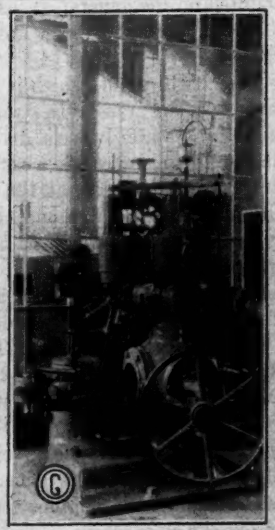
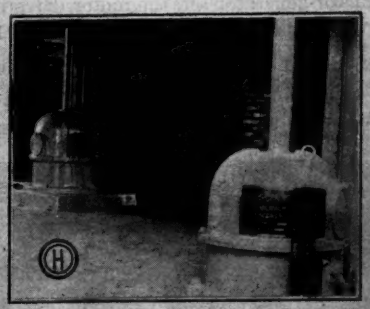


Fig. 5. Interesting Details of Equipment at Barton Plant

A—Switchboard at Barton plant carries various relays and meters and equipment for automatic and manual operation. Automatic synchronizing equipment is shown at extreme left of board. B—One of the pumps that supply oil at 150 lb. pressure for operating turbine governors. Their driving motors are connected to main power lines. C—This water-wheel exciter is used when the station is under normal automatic operation. D—Exterior of Barton plant, showing section of dam which provides average head of 26 ft. E—In this box are the telephone relays, the brain of the station, through which automatic operation is directed from Argo by a dial telephone. F—This is the 1000-kw. water wheel driven main generating unit. A 500-kw. unit, not shown here, is also installed. G—Oil-pressure type governor for one of the water wheels. H—Step bearings for two of the water wheels, the one in front being the exciter bearing, the other the bearing for one of the main units. I—This motor-generator set is provided as a spare and may be used in operating station manually.





described. At Barton, two Allis-Chalmers Mfg. Co. water wheels drive General Electric Co. generators, one 500-kw. unit driven at 120 r.p.m. and one 1000-kw. unit at 100 r.p.m. A water-wheel driven exciter is installed, consisting of a G.E. Co., 125-v., 400-a. d.c. generator, driven at 500 r.p.m. by an Allis-Chalmers water wheel as shown in Fig. 5C. This small unit is equipped as shown with a Woodward Type H.P. 1500-ft. lb. water wheel governor. Another exciter is installed, consisting of a General Electric Co. motor-generator set, the generator rated at 50 kw. at 1200 r.p.m. and 125 v., driven by a 75-hp. 2300-v. induction motor, shown in Fig. 5I.

Governors for the main units are of the Allis-Chalmers oil-pressure type, Fig. 5G. Oil for these is supplied at 150-lb. pressure by two Allis-Chalmers Co. rotary oil pumps, size 2, driven by 15-hp., 220-v., 60 cycle Allis-Chalmers motors. These oil pumps, one of which is shown in Fig. 5B, are duplicate installations arranged so that either one can be operated at a time. Thrust bearings are of the Allis-Chalmers plate type, the plate running on a thin film of oil and the bearing being submerged in an oil bath. Fig. 5H shows two of these bearings on the floor below the generators, the one in front being the thrust bearing for the water wheel exciter and the one behind being the bearing for the 500-kw. main unit. A small oil pump supplies oil to an elevated storage tank from which the steady bearings get lubricating oil.

The water wheels discharge into draft tubes of Gardner S. Williams design, which produce a vacuum of about 18 in. An open type of flume is used with two sluices controlled by motor-operated gates under the power house, which discharge into the draft tubes at high water. This is done to increase the vacuum in the draft tubes instead of letting the water go over the dam. An interesting point in connection with these draft tubes is that a vacuum cleaner system is piped direct from the tubes to be used in cleaning work about the station.

For filtering all oil used in the station a filter system was supplied by the Burt Mfg. Co. A two-stage American Steam Pump Co. centrifugal pump, driven by a 7½-hp., 220-v. G.E. induction motor pumps service water about the station. A Stevens Continuous Water Recorder, made by Leupold and Voelpel, is installed.

Voltage regulators, disconnect switches and other electrical equipment were furnished by General Electric Co. The automatic control equipment and its relays were supplied by Westinghouse Electric & Mfg. Co., as will be described. Voltmeters and ammeters are G. E. All water-wheel, generator and exciter bearings are fitted with Westinghouse type H.M. bearing thermometers. A 20-t. Whiting crane is provided in the turbine room to handle parts of the various units.

General Features of Automatic Control at Barton

Two 23,000-v. transmission lines run from Barton plant, one to Argo and the other to Dexter, where it connects into the system at a substation, as shown on the map, Fig. 1. Figure 5A shows the switchboard at Barton, which carries relays for automatic operation, as well as equipment for manual operation in case of emergency.

Each of the two generating units of the station feeds through an oil circuit breaker into the station bus system which is connected to the low tension side of two 2300 to 23,000-v., 3-phase, 60-cycle, transformer banks. The high tension side of these transformers is connected through oil circuit breakers and a bus tie to the protective equipment before leaving the station on the line west and lines east. Power for the 220-v., 3-phase oil pump motors and other auxiliaries is obtained by means of a 2300- to 230-v., 3-phase transformer bank, which connects on the high tension side, through double-throw, 3-pole disconnect switches, to the station bus system.

To provide a d.c. power source for the automatic devices and also for the operation of the supervisory equipment, a Westinghouse 100-v. storage battery is used. As the supervisory equipment requires 50 v. and as it is more advantageous to operate some of the smaller relays at this voltage, a tap is taken from the middle point of the battery.

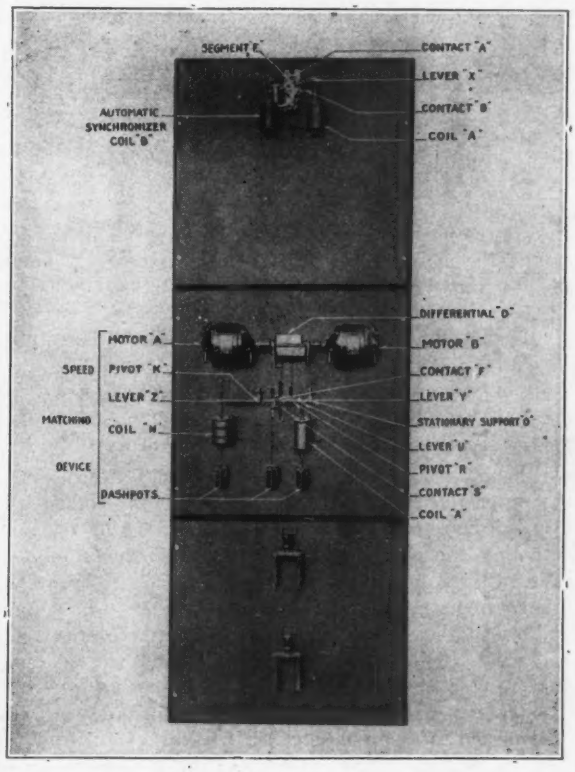


FIG. 6. SPEED MATCHING DEVICE, BELOW, ADJUSTS SPEED OF INCOMING MACHINE AND AUTOMATIC SYNCHRONIZER, ABOVE, CLOSES CIRCUIT BREAKER WHEN PHASE RELATIONS ARE RIGHT

Supervisory equipment is arranged to start or stop either of the two hydro-electric generating units, to indicate the head of water at the plant, to indicate the gate opening on either machine, to supervise the line circuit breakers. A trouble alarm system is provided to notify the dispatchers whenever any abnormal operation takes place in the station. Complete details of the supervisory feature are discussed under the heading of "supervisory equipment."

It would be unsafe to permit any unit in this plant to start up unless the oil pressure was sufficient to insure proper governor operation. The motor of each oil pressure pump is automatic in its operation and is connected to the system in such a manner that it will receive power from the system rather than from either of the generating busses.

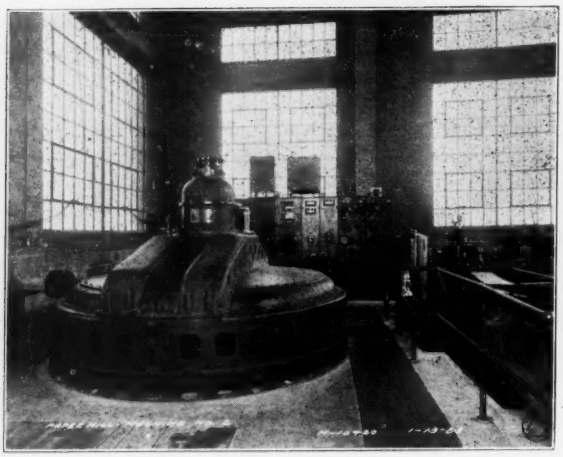


FIG. 7. ONE OF THE 400-KW. UNITS AT THE PAPER MILL PLANT, SHOWING PULLEY AT THE LEFT FROM WHICH ITS EXCITER IS DRIVEN

FIG. 8. SUPERIOR PLANT CONTAINS THREE GENERATING UNITS, THE ONE AT THE LEFT BEING A 250-KW. UNIT, THE CENTER ONE 450-KW. AND THE RIGHT HAND ONE 625 KV.A.

In case the pressure is low, a contact is opened in the circuit of the master control relays which renders it impossible to start the station until the oil pressure is sufficient.

Barton is Automatically Put on the System

To place the station automatically upon the system, assuming both units idle and that the system voltage and oil pressure are high enough, the operator at Argo dials his supervisory equipment in such a way as to close a telephone contact operating a master relay, which starts the water wheel driven exciter. The 100-v. storage battery is connected by relays across the governor solenoid, actuating the oil pressure valve, which admits oil and causes the gate of the turbine-driven exciter to open. As this gate opens, the exciter gradually builds up its voltage and, when this voltage is high enough, the exciter relay will close. The field contactor closes and places excitation voltage across the field of main generator No. 1. The gate operating motor opens the oil pressure valve controlling the gate mechanism of No. 1 unit and the machine starts, unless interrupted by the operation of some protective feature or by the operator. The master relay is energized by half of the 100-v. battery and cannot be energized unless the oil pressure for the main unit is above a certain value, maintained by contacts on the oil pressure gage.

When the speed of the unit is up to about 98 per cent of normal, the transfer relays connect the speed matching devices and automatic synchronizer to the control circuit of unit No. 1. A contact at the same time locks out the transfer relay of the other unit and prevents this machine from being transferred to the speed matcher until the first unit has been synchronized.

Speed Matcher and Automatic Synchronizing

The speed matcher, by controlling the operation of the gate raising devices, regulates the speed of the incoming unit to that of the line frequency. In the meantime, the automatic synchronizer has been watching for a chance to close the oil circuit breaker. When the voltages are in phase, it operates to close its make contact in the circuit of breaker control relay. Thereupon the oil circuit breaker closes, placing the generating unit on the system. Various relay operations then occur to de-energize the closing coil of the circuit breaker, the breaker remaining closed until released by the circuit breaker trip coil. The automatic synchronizing equipment is then released by the relays for use with unit No. 2. As soon as the oil circuit breaker is closed, a contactor gives full gate opening and, from that point on, the operation of the turbine is under the control of the governor. Before the circuit breaker is closed, the unit is running idle and resistance is connected in the field circuit to keep the generator voltage low enough for proper synchronizing.

Assuming that it is now desired to bring turbo-generator No. 2 upon the system, the Argo operator proceeds to dial so as to energize a telephone relay in the circuit of the master control relay of unit No. 2. As unit No. 1 is already in operation, the governor solenoid is energized, the exciter voltage is built up and relays function in the same manner as previously described for unit No. 1. Transfer relays of the second unit transfer the automatic synchronizing equipment to that unit and the machine is brought onto the line in the same manner as described for the first unit. If desired, the units may be started in the reverse order.

With both generating units running, if the system operator desires to stop one of the set, the supervisory equipment is dialed to energize the telephone relay which opens the master control relay. This causes the gate to be closed until the generator has entirely dropped its load. At this point, a cam operated switch located on the face plate connected to the gate opening mechanism, closes its contact in the circuit of the trip coil. The energizing of this coil causes the oil circuit breaker of the generator to open.

If it is necessary to start either unit for any reason from the Barton plant itself, the master control relay of the desired unit may be energized by means of the push button connected in the circuit of this unit. The automatic devices will now function and bring the unit onto the system in the manner which has just been described.

If, for any reason, it is desired to cut out the automatic synchronizing feature, the switch in the control bus may be opened. As this station was formerly manually operated it is equipped with the usual manual synchronizing devices.

If this station is to be manually operated, the operator may use either the water driven or motor driven exciter. If he uses the water driven exciter he has to operate the governor on this exciter by hand and thus bring the exciter up to the proper speed and then proceed to start up the main unit and synchronize the same as any manually operated station. If he desires to use the motor driven exciter, he starts that up and proceeds in the same way. Correct excitation must be obtained in the usual way by manipulation of the exciter voltage or through the rheostatic control of the field of the generating units. The manual operation is in all essentials exactly similar to that previously employed. The protective features are so connected that they operate to protect the equipment whether the set is operating automatically or manually.

Oil Pressure System

It has been previously mentioned that before this station can operate, it is necessary that the oil pressure reach a certain definite point and that it be held at or above this value. The motor driving this pump is connected onto the 220-v. a.c. 60-cycle house supply which is directly tied to the main system of the power company.

Upon a small contactor panel located adjacent to the pump motor are two oil pressure gages. One of these gages acts as a station lockout under a pressure of less than approximately 75 lb. per sq. in. The other gage controls the starting and stopping of the pump motor. It starts when the pressure goes down to 100 lb. and trips off when the pressure is 160 lb.

Details of Synchronizing Equipment

The automatic synchronizer for the Barton plant of the Detroit Edison Co. is shown in Fig. 6 and also at the left of the switchboard in Fig. 5A. As explained, under normal operation, when the speed of the incoming machine has built up to approximately 98 per cent of normal, the automatic synchronizer is transferred to that machine. The synchronizing equipment consists of two main parts, the speed matching device and the automatic synchronizer. The function of the speed matcher is to bring the incoming machine to the same electrical frequency as the bus, and when this condition has been obtained, the automatic synchronizer will wait for a chance to close the machine breaker when the phase relation between the machine and the line is correct. The speed matcher and the automatic synchronizer are operated from two potential transformers, one on the bus and the other on the incoming machine. The conditions, therefore, are the same as those in a hand operated station.

Speed Matching Device

The speed matching device consists essentially of two motors driving a differential, which actuates a brake band traveling through an angle of only a few degrees. The motion of this brake hand is transmitted by rod U, Fig. 6 to a system of levers X, Y and Z. These levers carry contacts that carry current for the anti-limiting coil N.

One of the motors, B, is driven from the secondary of a potential transformer on the bus; the other motor, A, is connected to a potential transformer on the machine to be synchronized. The connections are such that the motors run in opposite directions, thus it is evident that when the motors are running at the same speed the differential will not turn. If the incoming machine is running too fast, motor A will also be running a little faster than motor B, and the differential D will turn in proportion to the difference. This turning of the differential is then transmitted to the levers by the brake mentioned above. By means of the various contacts, the governor synchronizing motor then slows down the turbine unit by closing the gate. As the gates close, relays operate to drive the governor motor for several revolutions at intervals, thus it is "inched out" until motors B and A are running at the same speed. When the incoming machine is running slow, other contacts are brought into play and the operation is reversed. All movements of the lever system are damped by dashpot P.

Details of Automatic Synchronizer

The automatic synchronizer consists of main operating coils, A and B and the contact mechanism actuated by lever X, the ends of which are attached to the cores of A

FIG. 9. SUPERIOR PLANT, BETWEEN YPSILANTI AND ANN ARBOR, IS THE KEY PLANT OF THE GROUP, WHICH CONNECTS HERE WITH THE 120,000-V. TRANSMISSION SYSTEM

and B. Segment F is mounted loosely on the same shaft as lever X. Lever X is oscillating slowly, the position of F does not change, therefore, when the left hand end has reached the downward limit of its travel, contacts A and B make contact on the segment, closing the relays in the circuit breaker controls and throwing in the breaker. Since the movement of lever X is caused by the displacement of the brake band on the speed matcher, transmitted through the electric circuit containing coils A and N of the latter and A and B of the synchronizer, this movement is slow when the motors A and B are coming into phase and rapid when they are far out of step. The arrangement is made so that the contacts are closed slightly ahead of "in phase" position.

Connections are such that when the two voltages are in phase, the force of coil A is at its maximum and that of B is zero. Therefore, as the phase angle between voltages changes, the force of A and B will change, causing X to oscillate. The farther X oscillates, the more segment F is displaced, the quicker A makes contact or vice versa, A and B making contacts on segment F. If the phase angle is changing so rapidly that X is oscillating faster than once in four seconds, F is advanced so far that B is moved off the contact strip and when A closes, the circuit is still open, so the main circuit breaker will not close.

Details of Supervisory Control Equipment

In the Westinghouse audible type of supervisory control used at Barton plant, the station and apparatus units therein that it is desired to control or supervise are selected by the operation of a dial similar to that used in automatic telephony. Figure 5E shows the telephone relays as installed in the plant. The dispatcher is advised of the number of the station by an audible signal made by a bell, while a high or low tone indicates the open or closed position of the unit that is being controlled or supervised. The equipment is designed for use or operation over two line wires connecting the dispatcher's office or control station with the remotely disposed station. The magneto type telephone equipment may be operated over the same pair of wires without interfering with the successful operation of the supervisory control equipment. Several stations may be connected to the same pair of telephone line wires.

This equipment is designed to provide for the following functions: (a) to control and supervise the opening and closing of circuit breakers; (b) to supervise operations of apparatus units of any contact making type; (c) to obtain signals indicating the gate opening or the governor setting on a remotely disposed machine unit; (d) to obtain by means of a remotely disposed float switch an indication of the water head in a fore-bay; (e) to operate or release lockouts on machine units remotely disposed from the dispatcher's office.

Indications are as follows: signal for general trouble, howler; signal for station, single stroke bell also lockout on other stations on signal system; breaker tripped, high tone buzzer; breaker closed, low tone buzzer; water level or gate opening, high tone 6 or 8 buzzes, etc. Normal operation is indicated by a low hum in transmitter.

Complete protection of equipment at the Barton plant is afforded by various relays so that, in case anything goes wrong in the station during the absence of the resident operator, no damage is done. Relays are provided on the main generator bearings and exciter bearings which will protect the units against overheated bearings by shutting them down and sounding an alarm. In case the system voltage falls too low, low voltage relays operate to prevent the master relay, in the control circuit described above, from starting the units. Overload relays of the thermal type protect the winding of the units against overheating, while differential relays are provided to shut the units down in case of a breakdown of any of the stator coils. In case the exciter voltage is lost for any reason, field relays operate to stop the units. If the station is in any way separated from the rest of the system and the voltage of the units rises, over voltage relays will shut the units down before the voltage has risen too high. Finally, as described above, it is impossible to start the station until the oil pumps have raised the oil pressure high enough for proper governor operation. It is evident, therefore, that Barton plant is practically automatic in operation and can be controlled entirely from Argo. In case the operator at Argo finds on dialing that the Barton plant is shut down, he can get telephone signals that will tell him whether the shut-down has been caused by trouble on the lines, opening the circuit breaker, or by trouble in the station itself, which will result in shut-down of the units.

The method used in controlling Geddes, Paper Mill and French Landing from the key station at Superior is essentially the same as that described in the foregoing discussion of operation conditions at Barton plant. At these three plants the automatic and remote control devices were supplied by Allis-Chalmers Mfg. Co. and although these devices differ in constructional details from those described above, they perform similar functions.

For photographs and data used in preparing this article we are indebted to Geo. E. Lewis, Supt. of Hydro Plants, Detroit Edison Co., Ann Arbor, Mich., to the Westinghouse Electric & Mfg. Co. and to the Allis-Chalmers Mfg. Co.

In the Long Beach plant of the Southern California Edison Co., the 35,000-kw. generators are cooled with recirculated air, the latter being cooled by passage around coils through which sea water is circulated. During certain periods of the year considerable trouble is experienced due to the fact that the heat from the recirculated air is just sufficient to raise the temperature of the sea water to the proper degree to increase greatly the progagation of sea growth in the sea water. The growth of this sea moss soon covers the interior surface of the circulating tubes and greatly reduces the rate of heat transfer from the cooling air to the cooling water. During such periods it is necessary to clean the moss from the tubes at least once a week.

Heat flow meters for furnace walls are being studied by the Bureau of Mines, Department of Commerce. The purpose is to develop meters for the measurement of heat flow from kiln walls, boiler settings, surfaces of coal in mines, and similar problems. Seven meters have been constructed, 2 ft. square and about 3/22 in. thick, and have been partly calibrated by passing known rates of heat flow through them. When the calibration has been completed they will be available for special investigations on the flow of heat through refractory walls and for obtaining a measure of the radiation from boilers, kilns, etc., during an efficiency test.

High Pressures Make Progress

PROGRESS MADE SINCE WATT'S TIME AND OUTLOOK FOR THE FUTURE. BY MAURICE J. ZUCROW*

PROBABLY the value of high-pressure steam was known to James Watt (1774) but his conservatism kept him from experimenting in that direction. It is recorded that a successor of Newcomen built an engine to operate at 120 lb. per sq. in. pressure and Watt considered this to be such a hazardous undertaking that he endeavored to influence parliament to legislate against the employment of high-pressure steam.** Industrial activity in England, however, forced the rapid development of the steam engine, and steam pressures gradually increased.

The early nineteenth century saw many important developments based on scientific investigations: The science of thermodynamics was evolved (1824) from the works of Sadi Carnot, the inventor of the ideal cycle for heat conversion; of James Prescott Joule (1843) who pointed out that heat was a form of energy and determined its mechanical equivalent; of Prof. William Rankine (1851) and others. In addition to these, the classical experiments of Regnault (1847) on the properties of steam furnished engineers with reliable data for design purposes. The works of these men initiated a new era in steam prime-mover development based on more rational design.***

In 1883, Dr. Carl Gustaf Patrick de Laval, of Sweden, built his first steam turbine. Contemporaneously (1884) Sir Charles A. Parsons, of England, began his experiments which culminated in the development of the reaction steam turbine and the year 1901 marked the commercial production of Parson's turbines to compete with the reciprocating engine in the steam power field. At the close of the nineteenth century much progress had also been made in the development of the electric generator, which was a fortunate coincidence as the higher operating speed of the steam turbine enabled engineers to decrease the weight and cost of the electrical generators and the better space economy and greater power capacity of the steam turbine over the reciprocating steam engine could be utilized.

FROM 1900 TO 1914

Best practice in the art of steam generation at the time of the introduction of the steam turbine, is well illustrated by the Wildwood engine (1900), as described by Geo. A. Orrok. The operating pressure of this engine was 215 lb. per sq. in. gage, with 400 deg. F. steam temperature. Average central station practice in 1900 was to operate steam engines at pressures ranging from 150 to 175 lb. per sq. in. gage, most of the engines using superheated steam and the limit being 75 deg. of superheat, according to figures given by Mr. Monroe.

From 1900 until possibly 1914, the developments in central stations concerned themselves mainly with improving the vacuum at the steam discharge. It is highly probable that the condition of industry, due to the financial panics, prevented engineers from experimenting with higher steam pressures and as recently as 1914, steam pressures much in excess of 250 lb. per sq. in. were rare.

Since 1914, progress has been rapid. In the United States the urge to increase production occasioned by European war conditions, coupled with the country's growing prosperity, found steam pressures gradually rising. Progress made in this country during the war period, however, was accomplished mainly by the adaptation of existing apparatus to higher pressures, rather than by changes in design. Subsequent to that time, steam pressures have been increased cautiously by increments of 20 to 50 lb. per sq. in. The impetus to raise steam pressures has been the increased cost of fuels since the war period; a condition which is forcing engineers to concentrate their attention upon economical power plant operation. This is especially true of the European countries like Germany, where the fuel situation is stringent. Furthermore, the experiments of Dr. Wilhelm Schmidt with high-pressure steam, begun in 1910-11, have furnished engineers with a background of experience in generating and utilizing higher pressures.

RAPID PROGRESS SINCE 1920

Central station practice in 1920 is illustrated by the following quotation from that year's report of the Prime Movers Committee of the N. E. L. A. "At the present time 300 lb. with a total temperature of from 650 to 750 deg. F. may probably be taken as the conservative limit and under such conditions, a high degree of operating skill is required even when the best obtainable apparatus is installed. Smaller plants will probably find the economic balance in the neighborhood of 200 to 250 lb. and a total temperature not in excess of 600 deg. F., for sometime to come." By 1921, experience had shown that still higher pressures could be managed satisfactorily and the Report of the Prime Movers Committee of the N. E. L. A. for that year states that "350 lb. and 700 deg. F. are the upper commercial limits at the present." By 1921 the Teesbank Station of the New Castle Supply Co. in England was built, but this plant was then regarded as being highly experimental. This central station was designed by Merz and McLellan as early as 1917 and generates steam at 450 lb. per sq. in. and 650 deg. F.*

By 1922 the possibility of using pressures up to 350 lb. per sq. in. with temperatures up to 700 deg. F., was no longer considered to be in the field of experimentation, according to the Prime Movers Committee report. This was probably due to the better understanding of the behavior of power plant materials under high temperatures and to the better methods used in their production. Improved business conditions since 1920 also contributed to the progress. That period is conspicuous for the many experimental high-pressure steam developments and the intensive research in allied lines.

By 1923, central stations had been built or designed for pressures of 550 lb. and steam temperatures of 750 deg. F. Experimental plants for much higher pressures were in the process of construction both here and abroad. The consensus of opinion regarding safe working pressures by 1924 is apparent from the following statement taken from the June, 1924, Report of the Prime Mover Committee of the N. E. L. A.

*Engineering Experiment Station, Purdue University.
**Wm. S. Monroe, The Use of High-Pressure Steam, Trans. First World Power Conference.
***Sir James Kemnal, Steam Generation, Trans. First World Power Conference.

*R. H. Collingham, Electrician, June 19, 1925, The Use of Reheated Steam.

"During the past year, several base load plants have been under construction employing pressures of 500 to 600 lb. per sq. in. and temperatures of from 700 to 750 deg. F. Certain experimental turbines operating around 1000 to 1200 lb. per sq. in. pressure, and about 700 to 750 deg. are being installed in this country; and in England a plant carrying 3200 lb. pressure at the boiler, 1500 lb. at the turbine and about 800 deg. F. at the boiler is being built. These developments indicate that today (1924), when higher pressures are spoken of, pressures of 300 to 400 lb. are no longer referred to; pressures of this magnitude have become standard and the field covered by the term "higher pressures" has been advanced to pressures over 500 lb."

During this time thought and study were given to the development of new types of boilers for generating steam at the higher pressures. The most notable ones are the Benson and the Atmos boilers. These boilers have not as yet emerged from an experimental state, but there is promise of some material developments. In Sweden, an Atmos boiler of 1000 hp. capacity generating steam at 1500 lb. gage pressure has been built and another for 2500 hp. and the same pressure is in the process of construction."*

Report of the Prime Movers Committee of the N. E. L. A. for June, 1925, apparently places the high-pressure limit for base load plants at 550 lb. per sq. in. with a steam temperature of 700 to 750 deg. F. At that time, the Weymouth Station of the Boston Edison had under construction a unit for a pressure of 1200 lb.

Better Materials Needed

The struggle for higher pressures and steam temperatures has been largely one of materials. Of course, economic conditions also played a large part in the rate of development. George A. Orrok in his paper, The Commercial Economy of High Pressure and High Superheat in Central Stations, aptly summarizes the struggle with the following statement: "The rising pressure kept pace with improvements in materials and in the design and construction of steam generators and piping. Our engineers are now using better and more uniform materials than ever before (1922). Our metallurgical and manufacturing methods have been greatly improved. Copper, wrought iron, and cast iron have been discarded for boiler purposes." The materials for high-pressure and temperature services must be capable of resisting oxidation and corrosion and should maintain certain physical properties at the high temperatures. These requirements have led to the development of several alloy steels for boiler material and fittings and of several nickel copper alloys, like Davis metal, for valve seats. The recent adaptation of the X-Ray for detecting flaws in steel castings will, in the future, help to prevent failures due to non-uniformity in the quality of materials.

In Germany high steam pressures are being used only in a few industrial plants using back pressure steam. German engineers have been studying the question for several years, and the work of Dr. Wilhelm Schmidt has been instrumental in hastening the progress made all over the world in the adoption of higher steam pressures. Progress there has, however, been hindered in the past few years by the economic situation which compels German engineers to avoid the risk of constructing plants of an experimental nature and also by the French occupation of the Ruhr. In a paper before the Deutsche Zuckerindustrie and in another before the World Power Conference, O. H. Hartman refers to the Schmidt-Borsig high-pressure boiler, which is constructed under the Schmidt patents. This boiler generates steam at 854 lb. pressure. Each steam drum is forged from a single piece of nickel steel, the Krupp iron works having developed a 3 per cent and a 5 per cent nickel steel especially suitable for this service. Whereas, American boiler manufacturers use riveted drums for pressures as high as 750 lb. per sq. in., the German practice is to use the forged drums described for pressures much higher than 40 atmospheres (600 lb.). This type of boiler construction should facilitate the use of greatly increased steam pressure, since the drum wall can be forged to any desired thickness but has two drawbacks which probably prevent its general adoption. The drums are very expensive and their small size reduces the water and steam space of the boilers until it is insufficient to take care of the load fluctuations so that it becomes necessary to provide some form of steam accumulation except in base load plants using powdered coal.

TREND IN STEAM PRESSURES, 1774-1925

Date	Installation, Unit or Type of Station	Capacity	Steam Pressure Lbs. Per Sq. In.	Steam Temp. Deg. F.	Source of Information
1774	Engines of Watt		Atmospheric		
1810	Steamship Savannah		2.5		
1840	Steamship Britannia		12		Wm. S. Monroe. The Use of High Pressure Steam
1858	Steamship Gt. Eastern		24		Trans. of the First World
1876	Corliss Engine at U. S. Centennial Exposition at Philadelphia	2000 hp.	30		Power Conference.
1885	Parson's Turbine	4 kw.	60	308	
1888	Parson's Turbine	75 kw.	100	338	Richardson. History of the Parson's Steam Turbine.
1900	Parson's Turbine	1250 kw.	130	481	
1900	Wildwood Engine		215	400	Geo. A. Orrok.
1900	Average Practice		150–175	400–450	Wm. S. Monroe.
1902	Parson's Turbine	3000 kw.	138	595	Richardson. History of
1907 1910	Parson's Turbine	5000 kw.	200	508	the Parson's Steam Turbine.
1912	Parson's Turbine	25000 kw.	200	588	
1920	Large Central Stations		300	650	1920 Report of Prime
1920	Small Plants		200–250	600	Movers Committee N. E. L. A.
1921	Calumet Plants		300	650	1921 Report of Prime
	Springdale Plant		350	670	Movers Committee.
	Average Practice		200–275	600–650	
1922	American Central Stations		300–350	650–700	1922 Report of Prime
	Foreign Practice		About 400	up to 750	Movers Committee.
1923	Some Central Stations		400–550	650–750	1923 Report of Prime
	Most Central Stations		Up to 400	600–700	Movers Committee.
1924	Parson's Turbine	50000 kw.	550	750	Richardson.
	Some Am. Central Stations		500–650	700–750	1924 Report of Prime
	Am. Expt'l Plants		1000–1200	700–750	Movers Committee.
	Average Practice		300–400	700–750	
1925	Some Base Load Plants		550–650	750	1925 Report of Prime
	Average Central Station		300–450	700–750	Movers Committee.
	German Practice		About 515	750	Dr. G. Klingenberg.

Such high pressures as that used in the Borsig plant are the exception rather than the rule in Germany. German practice in large central stations is described in the following quotation taken from an article by Dr. G. Klingenberg, Berlin.* "Methods of constructing turbine blading and the materials available have permitted an increase in the steam temperature from 650 deg. to 750 deg. F. In the exigencies of operation that may, at times, be exceeded. German practice has not yet approved higher temperatures for turbine operation, since it is considered that reliability is more important than extreme economy. The limiting pressure at the boilers is about 515 lb. per sq. in. (35 atm.)."

The limit of steam pressures and temperatures has probably not been reached. Higher pressures and temperatures are used in oil refining and it is possible that much

*B. N. Broido, Recent Developments in the Use of High Pressure Steam, Engineering Soc. of Western Penn., Oct., 1924.

*The Modern Steam Power Plant, ZVDI, Oct. 10, 1925.

valuable and helpful information will be gathered from the experience of that industry. In this connection George A. Orrok makes the following statement: "Water has its critical temperature at 704 deg. F., and the critical pressure is about 3200 lb. Pressures up to this limit may, therefore, be considered and, since oil-still temperatures up to 1100 deg. F. have been used, we may consider superheat temperatures up to that point. We know that the first allotropic change in steel occurs at about 1300 deg. F. and 1100 deg. is well below that point. Here, however, we must look into the physical properties of the steels used in power plant construction."

Dr. Friederich Munzinger, the eminent German authority on this subject, remarked in a paper before the First World Power Conference, that the electric power stations of the future will use steam pressures from 570 to 1400 lb. and temperatures from 750 to 800 deg. F. At the same conference, Sir James Kemnal stated that he anticipated the use of steam pressures from 500 to 1500 lb. superheated to 750 deg. F. or higher and that the experience with pressures of 500 lb. is already sufficient to warrant the extra capital investment involved in higher pressures, in view of the expected increase in thermal efficiency.

Statements of these different European authorities and that of Mr. Orrok agree in substance. They predict that the power stations of the future will undoubtedly see higher pressures.

The trend in steam pressures from 1774 to 1925 is illustrated in the table herewith.

Changing Coal Into Liquid Fuel

By Dr. Carl Commentz*

AFTER years of research, Dr. Frederick Bergius, of Heidelberg, Germany has developed a process for liquefying coal by the addition of hydrogen under pressure. This was done with the purpose in mind that the future production of mineral oils will not cover the demand and that Europe, especially, will have to rely upon artificial production of suitable fuel oils.

Initial developments of the Bergius process were made before the War. From 1910 to 1913, Dr. Bergius investigated the structure of coal and by a certain chemical reaction succeeded in producing coal-like materials from wood. With this reaction there was always produced, in all cases, the same amount of carbonic acid and water. By comparing this process with similar chemical reactions, it could be deduced that it ought to be possible to convert the molecules of coal into hydro-carbonates by the addition of hydrogen. The problem of such addition was solved in connection with a special cracking process of heavy oils which was being conducted at the same time. This cracking process differs entirely from other well-known processes serving to change heavy oils into lighter oils. Under a pressure of 1400 to 1700 lb. per sq. in. and at a temperature of about 750 deg. F. it was found possible to add hydrogen atoms to the molecules of heavy oils.

This procedure then was tried in the summer of 1913 with coal which was put into a high pressure vessel and subjected to a hydrogen pressure of approximately 1500 lb. at a temperature of approximately 700 deg. F. The reaction proceeded for several hours and after cooling, there was found a mixture of gas, oil and only about 15 per cent of insoluble residues. Later on it was found that when the vessel was revolved better results were obtained.

For average coals the most favorable temperatures for hydrogenation are between 840 to 900 deg. F. and the time of treatment is about 16 min. Before application of heat, the initial pressure must be at least 1070 lb. per sq. in. If the pressure is insufficient, no hydrogenation will result. Within certain limits an increase in pressure results in an increase of oil production.

Difficulties Overcome by Mixing Oil with Coal

To develop a plant for continuous operation on an industrial scale considerable technical difficulties had to be surmounted. A practical way was found only when the discovery was made that it was possible to force paste-like mixtures of coal-dust and oil by specially constructed pressure pumps through the vessels filled with hydrogen. A good paste was made by mixing 220 lb. of finely ground coal with about 88 lb. of tar oil, the particles of coal-dust having a size of about 0.04 in. diameter. Mixing coal with oil has the advantage that the distribution of heat during the chemical reaction is much improved and coking is avoided.

In practical operation the hydrogenation plant consists of a pressure pump in which the mixture is put under a pressure of 2140 lb. per sq. in. and then brought into the initial mixing vessel and mixed with the hydrogen by a special stirring apparatus. The reaction takes place in a second pressure vessel. The material is then cooled and the pressure relieved by a relief valve. From here the mixture is taken to another vessel where it is separated into gas liquid and solid parts.

When starting the plant, tar oil was first mixed with the coal dust but later on the oil generated by the process was used and various kinds of coal were treated. Exceptional difficulties were found in heating the pressure vessels because the strength of the iron was much reduced at the temperature used. A new method of heating was developed, therefore, in which the heat was transmitted to the vessels by a compressed gas which is chemically inert. This gas was heated in a special superheater, circulation of the gas being effected by special pumps. Before being heated in the superheater, the gas was preheated by the hot material leaving the pressure vessels. The amount of fuel for heating was, therefore, quite small. By this method of heating it is possible to keep the temperature at the same degree for weeks if necessary.

For industrial plants the necessary pressure in hydrogenation is about 2100 lb. per sq. in. In order to make the process economical, it was necessary to find a means of generating hydrogen at low cost. It was found that the necessary hydrogen could be obtained from a coke-producing plant co-operating with the Bergius plant. The gas produced in the latter plant, being more valuable than coke gas, could then be used for other purposes.

By the Bergius process of liquefying coal, only 2 to 3 t. of coal are required for generating 1 t. of oil, the exact amount depending on the kind of coal. The cost of labor is low because most of the work is done mechanically. The economy of the process, therefore, depends largely on the relation between the prices of coal and oil. As cheap coal-dust may be used, the future of the process seems favorable. Important officials of the German coal industry favor the idea of erecting these coal liquefying plants.

*Civil engineer, Hamburg, Germany.

Furnace Changed for Powdered Coal Is a Success

Details of Alterations at Ashley Street Station, St. Louis.* By E. H. Tenney**

FURNACE changes at Ashley Street Station were undertaken early in 1925 for the purpose of increasing boiler capacity and efficiency and eliminating smoke, these to be effected by larger water-cooled furnaces fired with powdered coal. It was further expected that operating costs would be substantially less than with the older equipment, the low grade of fuel used having been the source of high operating expense, particularly at high boiler ratings.

Unit type of pulverizers were chosen, largely because the physical arrangement of the equipment already operating was not suited to the application of the central pulverizing system without an unjustified cost. Such a system would require a new building for the milling equipment and space for driers, conveyors, powdered coal transport piping, storage bins, feeders, etc., the installed cost of which was not consistent with the economies to be expected.

It was found, in the test installation, that a furnace volume of approximately 3200 cu. ft. was required, which is 5.75 cu. ft. per rated boiler horsepower. It was also determined, in this test installation, that a certain speed and turbulence of the fuel and air must be set up by the burner, if early ignition and complete combustion of the fuel were to be effected within this space.

Straight shot burners resulted in late ignition and erosion of the rear furnace wall. A burner is therefore used which supplies with the coal from 50 to 80 per cent of the air required for combustion, the remaining 50 to 20 per cent of secondary air being admitted through deflection vanes which surround the fuel nozzle. This secondary air supplies the necessary turbulence immediately in front of the burner.

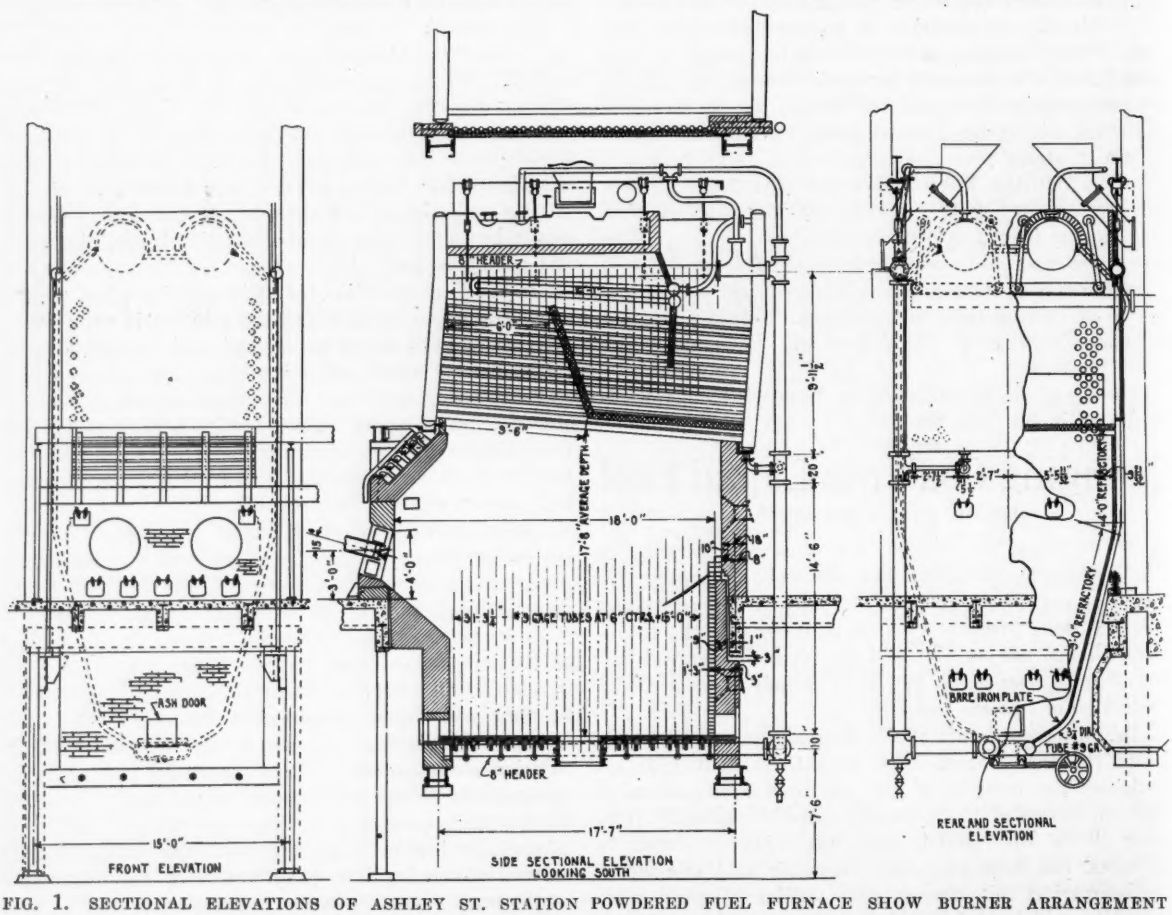


FIG. 1. SECTIONAL ELEVATIONS OF ASHLEY ST. STATION POWDERED FUEL FURNACE SHOW BURNER ARRANGEMENT AND WATER-COOLED WALLS

Wall Construction

In view of our experience at Cahokia with air-cooled walls, it was decided to install water-cooled walls in the Ashley Street furnaces, which would permit of sustained high rates of combustion without damage. This we decided could be most effectively accomplished by the use of the refractory faced blocks developed by the Bailey Meter Co., a construction which made it possible to do away with all the brick work in the boiler and furnace setting, except for the front and rear walls of the furnace. Bare cast-iron blocks were used on the lower section of the furnace to prevent possibility of slag formation. With this

* From a discussion before the Midwest Power Conference.
** Chief Engineer of Power Plants, Union Electric Light and Power Co.

construction it is possible to operate at rates in excess of 300 per cent continuously without formation of molten slag in the furnace and without injury to the furnace walls.

We now have eight of these furnaces installed and in operation. Figure 1 shows the elevations of boiler settings.

In the installation of this rather radical departure in furnace construction and arrangement there have, of course, been many interesting problems to be met. These problems center around the mill, the burners and the furnace.

Pulverization and Air Supply

(a) The unit pulverizer on the first eight boilers is the Simplex Mill of the Furnace Engineering Co., Fig. 2. The mill is rated at 8000 lb. an hour and has actually pulverized 8700 lb. of coal an hour. The coal contains 12 per cent water and 13 per cent ash. The quantity of primary air that is mixed with the coal at the outlet of the mill and delivered with the coal at the furnace is controlled by dampers in the suction of the fan, the quantity of air necessary to sweep the mill being regulated from the coal admission end. There is sufficient flexibility in the fuel and air supply to give any mixture that may be required by the condition of the burners or furnaces. Continued study and experimentation are being made on this unit with the idea of increasing its tonnage and decreasing its power consumption, which, at present, is approximately 15 kw.-hr. per ton of coal.

Burners and Arrangement

(b) Problems arising in connection with the burners have also been numerous and interesting. On the first furnace, of the type shown in Fig. 1, three burners were installed, one at the bottom of the furnace and two above, as shown.

It was found that the lower burner prevented the fuel from the upper burners sweeping down through the furnace sufficiently for complete combustion, hence the bottom burner is now omitted. Use of two burners at the upper location proved to be entirely satisfactory, especially when they were tilted down 20 deg. from the horizontal. The velocity of fuel and air leaving the burners had also to be worked out with relation to the width and length

FIG. 4. THE FRONT WALL HAS TWO BURNERS, SUPPLEMENTARY AIR SUPPLY AND ASH DOORS

of the furnace and in relation to the necessary turbulence of the flame. It was found that too great a turbulence resulted in losses, but of a different nature from those experienced with the straight shot burner.

Adjustments of the cone spreader at the end of the coal feed pipe had to be made also, with reference to the velocity and spread of fuel and in relation to the percentage and velocity of secondary induced air. We even put secondary air through the burners under pressure but found, in the light of results obtained, that this was unnecessary.

(c) Some of the problems in connection with the

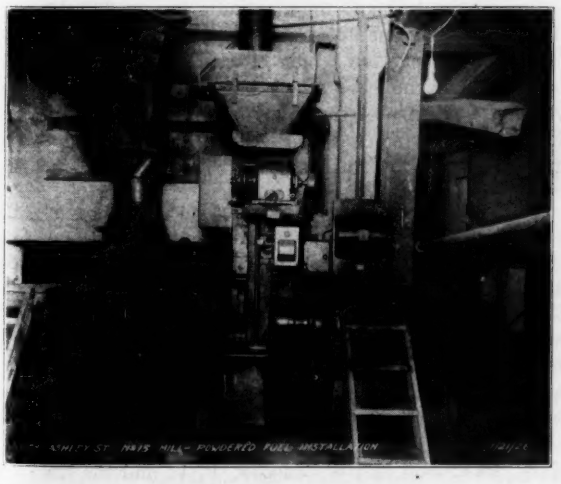


FIG. 2. UNIT PULVERIZING MILLS WERE USED TO AVOID EXPENSIVE ALTERATIONS

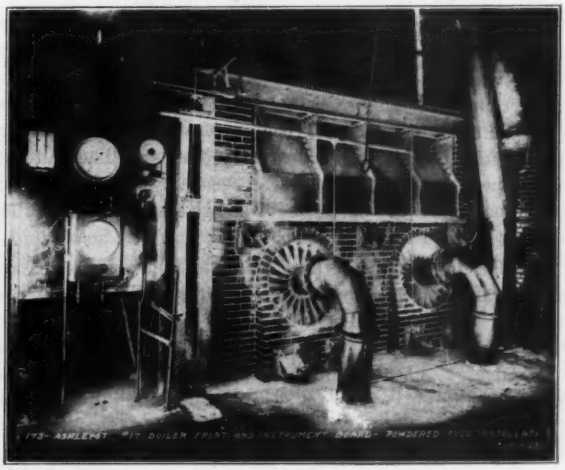


FIG. 3. DOWN SHOT BURNERS ARE INCLINED AT 20 DEG. FROM THE HORIZONTAL. CONTROL IS FROM AN INSTRUMENT BOARD

furnace arrangement had to deal with the quality of the refractory best suited permanently to withstand the temperatures developed, and this was found to be a mixture of alundum and fire clay. These side-wall blocks, which are cemented to the tubes and held in place by clamps bolted to the blocks, were found to give the most satisfactory results when the so-called precast refractory was used. This block is manufactured by having the iron cast around the refractory, the result of this being that the cast iron, on cooling, seizes the refractory so that, even at the highest temperatures developed in the furnace, the refractory remains tight in the casting. Later experiments, where the refractory was plastered into the

FIG. 5. SIDE WALLS ARE WATER-COOLED BY TUBES AND FACED WITH REFRACTORY BLOCKS HELD IN CAST IRON MOUNTING SHELLS

block after being placed in the furnace, developed the fact that this refractory sometimes loosened from the blocks and reduced the conductivity to such an extent that it was ultimately damaged and had to be replaced. It was on account of this experience that all of the refractory faced blocks in the Ashley Street furnace equipment are of the precast construction, Fig. 5.

With these water-cooled walls there was a reduction of about 60 per cent in the temperature of steam leaving the boiler, and for this reason we have supplemented the convection type superheaters with radiant superheaters located in the rear wall of the furnace, thereby bringing the superheat back to the original 150 deg. The radiant type superheater is of the Power Specialty Co. design and is composed of eleven rows of forged steel superheater sections located as shown in Fig. 6.

One of the problems that had to be met on this installation was that of handling ash from the bottom of the furnace. Ashley Street Station is equipped with two decks of boilers, the powdered coal installation on the lower deck. The ash hoppers serving the upper deck boilers could not well be disturbed, and the presence of these hoppers had a great deal to do with the shape of the furnace as finally installed on the lower floor. Openings in the bottom of the lower deck furnaces permit the dumping of accumulations of ash direct into cars below.

In this installation the capacity of the induced draft fans limits the capacity to which the boilers can be driven. These fans have sufficient supply for two stoker-fired boilers operated at 200 per cent rating and at 11 to 12 per cent CO_2. To operate at 300 per cent of rating with the same fans, it is necessary to maintain 15 per cent CO_2. This, of course, means that the furnace temperatures are exceedingly high and it is for this reason that we have taken the particular steps, pointed out above, to make operation possible at these high ratings without damage to walls or slagging of tubes or furnace bottom.

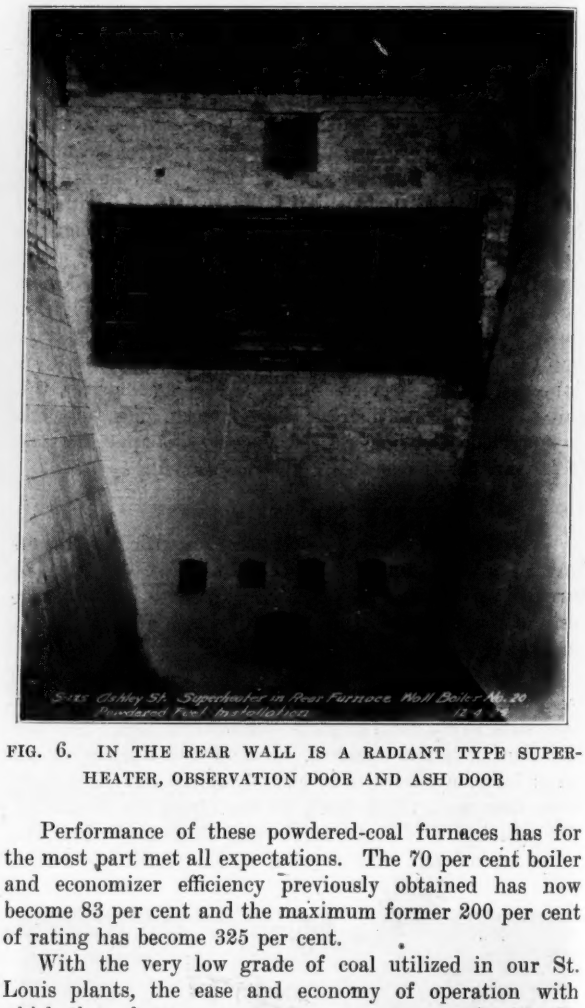


FIG. 6. IN THE REAR WALL IS A RADIANT TYPE SUPERHEATER, OBSERVATION DOOR AND ASH DOOR

Performance of these powdered-coal furnaces has for the most part met all expectations. The 70 per cent boiler and economizer efficiency previously obtained has now become 83 per cent and the maximum former 200 per cent of rating has become 325 per cent.

With the very low grade of coal utilized in our St. Louis plants, the ease and economy of operation with which these furnaces are now run, as compared with the many difficult and wasteful conditions previously experienced, even at low ratings, are of such an extent as to be worthy of this especial attention.

OFFICIALS of the Montaup Electric Co. are considering the erection of a second unit for the plant at Somerset, Mass., at a cost of $2,000,000. The initial unit, recently completed, has a capacity of 32,000 kw. and this would be doubled by the erection of a second unit. The present plant of the company is valued at $8,500,000 of which $5,000,000 is situated in Somerset. The plant supplies power and light service to Fall River and Brockton, Mass., Pawtucket and Woonsocket, R. I., and the lines are to be extended to Taunton, Mass., all thriving industrial cities.

Furnace Design for Traveling Grate Stokers---II**

When Burning Fine Sizes of Anthracite or Coke Breeze, the Length and Slope of the Rear Arch Are of Prime Importance. By H. S. Colby*

IN COMPARING the single arch furnace with one having both front and rear arches, it is found that with the former design and the limited length of gas travel from fuel bed to boiler heating surface, the diffusion of the gases is but slight and at practically all ratings a trace of carbon monoxide can be detected at the extreme front end of the gas passage, that is, close to the front curtain wall and front headers. The stream of gas of proper composition goes up through the center of the tube bank and to the rear of this stream is a stream of dilute gas representing the infiltration of air through the rear end of the fuel bed.

For practical operation, with the single arch furnace, proper air distribution was so difficult that incomplete combustion scarcely ever could be entirely eliminated.

Front and Rear Arches Give Better Combustion Control

With the double arch furnace the distribution of air can be modified as compared with the single arch so that the zone of highest incandescence can be carried further back on the stoker. For the combustion of the hydrocarbons and carbon monoxide generated under the front arch, it is unnecessary to attempt to introduce air close to the point of generation. This means that the amount of air delivered to the first and second zones can be reduced and increased on the third and fourth zones. Reducing the amount of air delivered to the first and second zone increases the rapidity of ignition, the fuel bed becoming incandescent clear through to the grate surface at a somewhat earlier period. The maximum combustion rate obtainable is, therefore, appreciably increased. This design also permits introducing sufficient air through the last compartment to reduce the combustible in the ash residue to a minimum.

Gases containing an excess of oxygen from the rear zone are diverted by the rear arch into the stream of gas somewhat deficient in oxygen from the front of the stoker. These streams, flowing in opposite directions, as they pass up through the restricted throat, become intimately mixed with the gas of extremely high temperature generated on that section of the fuel bed directly below the throat. This intimate mixing at high temperature results in complete combustion within a relatively short distance from the point of mixing. With the low settings as formerly found, combustion was not complete before the gases entered the tube bank, but with the higher settings of today this ideal condition more often prevails.

Proportioning of the arches, that is, relative length of front and rear arches and throat area (space between the arches) is influenced by the analysis of the fuel and more particularly by the volatile content. For the burning of coking or semi-coking coals of complex volatile content the front arch should be quite long in order to allow sufficient time for the breaking down of the complex hydrocarbons into simpler forms and the burning of the latter before the gas enters the tube bank.

With free burning, high volatile coals the front arch can be much shorter and also should be set considerably higher. The throat area also must be increased. This is due to the fact that the hydrocarbons start to burn much more quickly and with the increased volatile content, for any given capacity, the volume of gas is much increased. In burning high volatile coals, it is essential to provide a higher setting due to the fact that the wider throat area does not permit as intimate a mixing of the dilute gas from the rear with the rich gas from the front of the stoker as obtained with the narrower throat used with coal having lower volatile. From the point of mixing to the boiler heating surface the time element must be increased to provide for complete combustion before the gas reaches the boiler heating surface. This necessitates higher settings, or with low settings, the admission of air above the fuel bed.

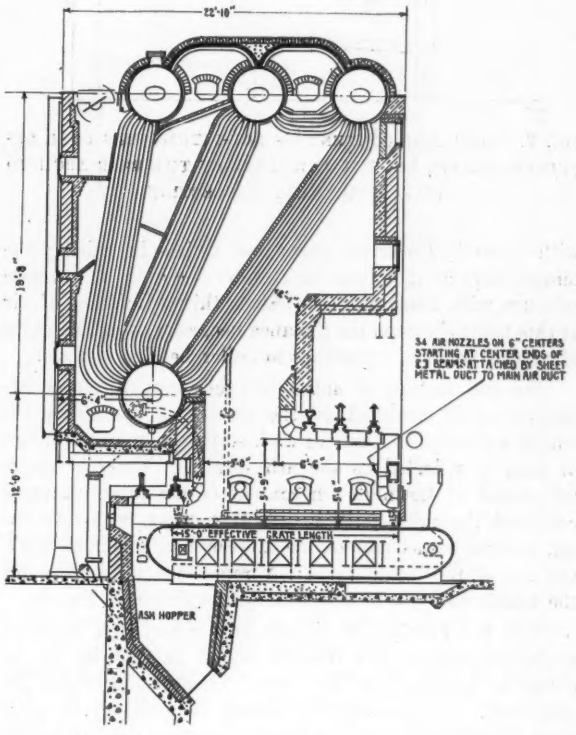

22'-10"
34 AIR NOZZLES ON 6" CENTERS STARTING AT CENTER ENDS OF I3 BEAMS ATTACHED BY SHEET METAL DUCT TO MAIN AIR DUCT
15'-0" EFFECTIVE GRATE LENGTH
ASH HOPPER

FIG. 1. FOR BURNING HIGH VOLATILE BITUMINOUS COAL AT A HIGH COMBUSTION RATE, THIS ARRANGEMENT OF FRONT AND REAR ARCHES IS USED

Admission of Auxiliary Air Necessary

Figure 1 illustrates a typical arch arrangement for the burning of high volatile coal with a boiler of moderate setting height. Air is admitted through a series of nozzles located in the ignition arch for the purpose of providing oxygen to support the combustion of the low temperature distillation hydrocarbons which are liberated over the first and second compartments of the stoker. Admitting air at this point brings it in intimate mixture

*Assistant sales manager, Riley Stoker Corp., Worcester, Mass.
**Part I of this article appeared in the March 1, 1926, issue.

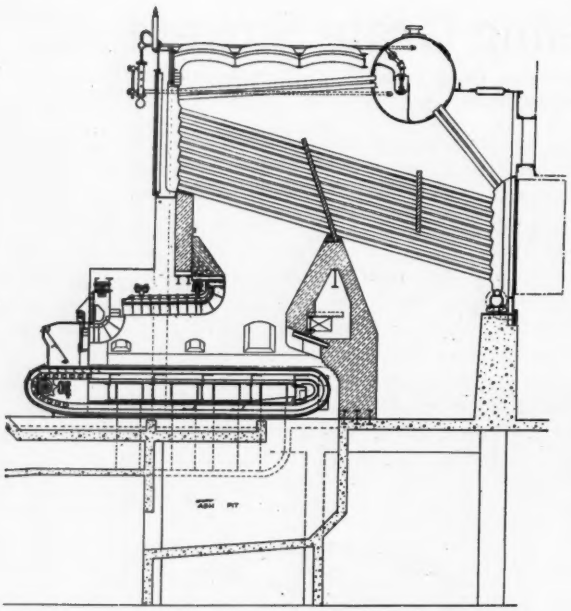


FIG. 2. HIGH ASH CONTENT OF SUB-BITUMINOUS COAL REQUIRES GREATER LENGTH AND SLOPE OF THE REAR ARCH TO GIVE MORE HEAT REFLECTION

with these hydrocarbon gases and assists in raising the temperature as it travels back under the arch in intimate mixture with these gases. Besides this, admission of air at this point shortens the distance necessary from the point of mixing between the arches to boiler heating surface.

For the burning of sub-bituminous coal, this arch arrangement is modified to the extent of increasing the length and slope of the rear arch so that a greater amount of heat is reflected to the ash residue. This change is occasioned by the high ash content of the sub-bituminous coal and the necessity for reflecting more heat into the ash residue on account of the increased difficulty of burning out of the combustible. A representative setting for the burning of sub-bituminous coal is shown in Fig. 2.

For the burning of lignite and other high moisture coals, the double arch furnace design is modified to the extent of lengthening the front arch and shortening the rear arch. Lengthening the former is necessary in order to replace the effective combustion surface used to evaporate the high moisture content over the first compartment of the stoker. A typical furnace design for the burning of lignite is shown in Fig. 3. Generally lignites are of relatively low ash content and little difficulty is experienced in reducing the combustible in the ash to a minimum. The rear arch, accordingly, is much reduced, since, being in the zone of highest temperature, it is highly effective.

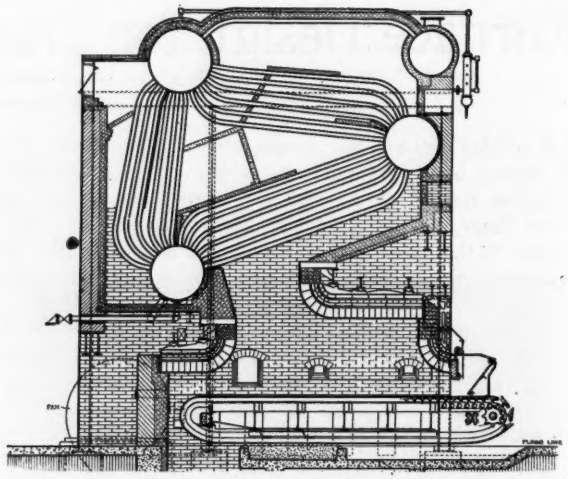


FIG. 3. TO GET BEST RESULTS WITH LIGNITE THE FURNACE DESIGN SHOULD BE SIMILAR TO THIS

To determine the effect of the rear arch, a series of experiments were made with traveling grate stokers under 600-hp. Babcock & Wilcox boilers, set 11 ft. from the floor to the bottom of the front header. The stokers were 11 ft. wide by 13 ft. long. In Table I the data on three tests is shown at a combustion rate of 33 lb. of coal per sq. ft. of grate surface per hr. which represents the point of normal operation. Data in the first line was taken with a furnace design substantially as shown in Fig. 1, March 1 issue. The second line was with a furnace design having a short rear arch and the third line was with a furnace design having a much longer rear arch, being substantially as shown in Fig. 2, March 1 issue. It will be observed that 4.5 per cent was added to efficiency with the adoption of a short rear arch and practically 7.5 per cent by the adoption of a rear arch of the proportioning shown in Fig. 2, March 1 issue.

(To be concluded)

TABLE I. AFTER CHANGING FROM THE FURNACE DESIGN SHOWN IN FIG. 1 TO THAT OF FIG. 2, ALMOST EIGHT POINTS WERE ADDED TO THE EFFICIENCY

Design of Furnace Shown in	Duration, hr.	Steam pressure, lb.	Degrees superheat	Feed water temperature	Flue gas temperature	CO_2, last pass, percent	Total weight coal as fired, lb.	Total weight dry refuse, lb.	Total weight water fed to boiler, lb.	Coal analysis, (as fired) E. bituminous: Fixed carbon	Volatile matter	Ash	Moisture	B.t.u. per lb.	Combustible in dry refuse	Coal per hr. as fired	Coal per sq. ft. grate	Equivalent evaporation per hr., lb.	Equivalent evaporation per sq. ft. of heating surface, lb.	Boiler hp. per hr.	Percent rated capacity developed	Actual evaporation per hr. per lb. coal, lb.	Equivalent evaporation per hr. per lb. coal, lb.	Efficiency of boiler, furnace and grate, percent
Fig. 1	11.0	234	82	201	571	—	51663	5365	433144	67.90	18.80	6.44	4.86	13249	33.43	4697	32.8	43944	7.32	1274	212	8.38	9.53	68.6
Not Shown	12.0	227	138	211	566	13.3	56543	5932	505884	71.00	16.60	6.90	5.50	13495	-	4710	33.0	47867	7.97	1395	232	8.94	10.17	73.1
Fig. 2	9.0	237	144	167	539	13.7	43617	2789	365005	63.76	15.46	11.08	9.70	12651	22.24	4846	33.8	48126	8.02	1395	232	8.26	9.92	76.1

Plant Additions Result in Large Savings

Installation of Small Condensing Turbo-Generator Units and Water Treating System Greatly Increases Flexibility of Plant. By W. R. Hoback.

IT IS AN EASY thing to overlook the fact that many small industrial plants offer power plant problems which are important and require considerable scheming and thought for their solution. One example of this kind is the recent change in plant arrangement and capacity which has been made at The Gager Lime & Manufacturing Co. at Sherwood, Tenn.

Consideration of the power problem was brought about because of an increase in the business of the company which necessitated the installation of a new kiln as well as additional quarry and crushing equipment. This plant was already electrically driven throughout and contained a total connected load of 16 motors which aggregated a total of 366 hp. The additional load which was necessary because of greater manufacturing facilities was that of six motors which were rated at a total of 225 hp., thus making the new motor load 591 hp.

In the old plant were two 100-hp. return tubular boilers set in a battery and one Stirling water-tube boiler set singly. The boilers were operated at 160 lb. ga. pressure and the steam was furnished without any superheat. The electrical equipment consisted of one 250-kv.a. General Electric Co. turbo-generator operating non-condensing, exhaust steam being supplied to the kilns at about 2 lb. back pressure. For use at night there was a 75-kv.a. belted generator which was driven by a high speed steam engine. The current was generated at 3-phase, 60 cycles and 440 v.

This voltage had been selected because some electric power was transmitted to the top of the mountain, adjacent to the plant, where the quarry is located and the lime stone crushed to proper size before being transported from the quarry to the plant. More steam was furnished by the 250 kv.a. turbine unit than was required by the kilns. There was a waste therefore at this point. No data were available regarding the true amount of steam actually required by the kilns, therefore a steam flow meter was installed and that information obtained.

As would have been expected, the load factor, when checked, was found to be about 50 per cent, which is typical of this kind of manufacturing plant. The anticipated load with the new equipment in operation was estimated at 286 kw., therefore it was decided to install a new turbine unit the rating of which would be 375 kv.a. (300 kw.)

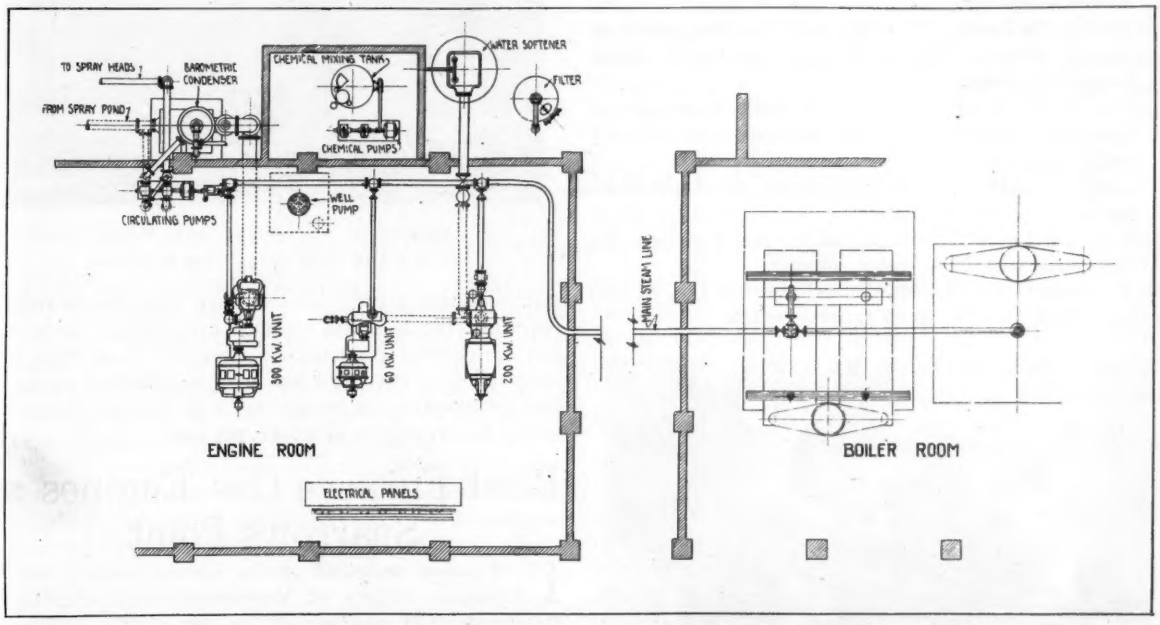


FIG. 1. GENERATORS ARE HOUSED IN A SEPARATE BUILDING FROM THE BOILERS

As the high speed steam engine was in bad condition, it was proposed to install a new non-condensing turbine for this 75 kv.a. generator and use this for the supply of exhaust steam to the kilns. By operating this in parallel with the 375-kv.a. unit, the amount of exhaust steam could be controlled to the exact needs by varying the load on the 75-kv.a. unit. The new turbo-generator unit was operated condensing, in order to obtain maximum economy, and the present 250-kv.a. non-condensing unit was to be installed in the new power house and arranged to operate in parallel with the two units just mentioned. As the economy of the 250-kv.a. unit was inferior to that of the 375-kv.a. unit, it naturally assumed the role of an emergency unit.

One problem of great importance in connection with these improvements was that of the type of condenser to be installed. The feed water, taken from a well, was bad, averaging about 41.5 gr. of scale forming solids per gallon. Of the total solids 25 gr. was calcium sulphate. At first, consideration was given to a surface type of condenser in order to obtain condensate for boiler feed water. Upon further consideration it was found that about one-third of the steam generated was fed to the kilns. This steam is fed under the grates and is therefore lost.

Another serious disadvantage of the surface condenser, was the fact that a spray cooling system was necessary to obtain a supply of condensing water. As the loss from this spray pond is by evaporation, it has the effect of concentrating the solids in the circulating water. The scale problem is, therefore, transferred from the boiler to the condenser, where it is far more troublesome and more expensive to deal with. The recommendation was therefore made that a barometric condenser be used, and a water softener be installed to treat the boiler feed water. This was adopted as the best means of doing away with boiler scale and condenser trouble from the same cause.

The new equipment installed was as follows:

1—450-hp. De Laval condensing steam turbine, geared to a 375-kv.a. General Electric Co. generator with direct connected exciter.

1—100-hp. De Laval condensing steam turbine, geared to 75-kv.a. General Electric Co. generator with direct connected exciter.

1—4-in. De Laval vertical centrifugal pump, motor driven, installed in well for supplying makeup water to spray cooling system.

1—5-in. De Laval combined motor driven condenser circulating and spray pump.

1—2-in. De Laval centrifugal pump, motor driven, for raw water supply to water softener.

1—Four-panel switchboard, General Electric Co., of natural black slate to match existing panels.

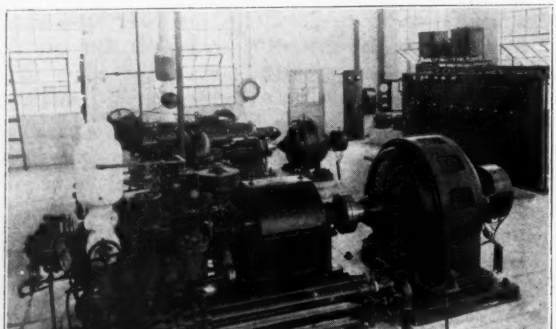


FIG. 2. NEW CONDENSING UNIT IS IN THE FOREGROUND

1—General Electric Co. voltage regulator, suitable for controlling three generators.

1—Barometric condenser with steam jet air pump.

1—Cochrane hot process water softener, capacity 3200 g.p.h., complete with automatic proportioner, chemical pumps and pressure filter.

1—Cochrane flow meter for measuring steam delivered to kilns.

1—Spray cooling system, using Badger non-clog nozzles, capacity 630 g.p.m.

Arrangement of this equipment is as shown in the accompanying Fig. 1. The boiler room was left as it originally stood, the boiler capacity being sufficient to take care of the additional load. The turbine room is a new structure built separate from the boiler room. The condensing unit was placed nearest to the spray pond and the two non-condensing units were placed parallel and piped up so that part of the exhaust steam would go to the heater and the remainder to the kilns. It is interesting to note that the water softener and filter are located outside of the building. The chemical mixing tanks and pumps are housed in a lean-to built against the turbine room wall.

This plant was finished and started early in 1924, without interfering with the regular operation of the

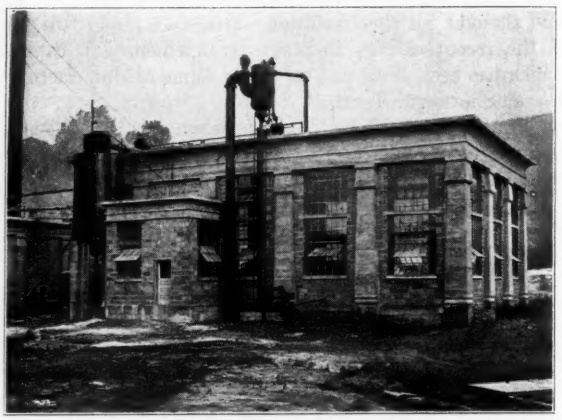


FIG. 3. BAROMETRIC CONDENSER AND WATER TREATING PLANT ARE OUTSIDE OF THE BUILDING

manufacturing plant. After the new plant was in regular operation, the load was changed over and the generator and switchboard from the old plant moved to their new location. The new plant has made a gratifying saving in fuel consumption, in comparison with the old plant, this saving amounting to about 50 per cent.

Blast Furnace Gas Engines at Sparrows Point

IN A paper presented at the annual meeting of the American Society of Mechanical Engineers, A. A. Raymond, chief engineer of the gas engine department of the Bethlehem Steel Co.'s plant at Sparrows Point, told of the twelve blowing engines and six generator-unit engines operated on blast-furnace gas. The blowing engines are 2-cylinder double-acting, 4-stroke cycle, five with gas cylinders 45 in. diam., and air cylinders 80 in., seven with diameters of 47 and 84 in., the stroke of all being 60 in. Generating units have four cylinders in twin-tandem arrangement 47 in. diam. by 60-in. stroke at 88.3 r.p.m., driving 25-cycle, 6600-v. generators of 4000-kw. capacity at 80 per cent power factor.

Gas passes through eight Theisen washers, each with capacity of 850,000 cu. ft. per hr. and driven by a 150-hp. motor at 355 r.p.m. All discharge to a common main which supplies the engines and also connects to a 202,000 cu. ft. gas holder, flow to and from which is controlled by an automatic valve operated by a gasometer.

About half the cooling water for the engines is salt water, the blowing engines using 4800 gal. of water each per hour, and the generator engines, 15,000 gal. This water enters the cooling system at 85 deg. F. and leaves at 145 deg., being then cooled by spraying.

Air for starting is supplied by motor-driven compressors and stored in fifteen tanks at 200 lb. sq. in., the engines being supplied from a common main.

Cast steel cylinders are used because of greater strength,

better cooling effect, safety under tension, higher permissible temperature, better possible design of valve parts and lighter weight with greater strength. Cast steel is also used for pistons for much the same reasons, spherical shape being adopted as nearly as possible, with deep packing rings to prevent wear on the sides of grooves and piston rod bored for cooling water from both ends.

Rod packing is of cast-iron segmental rings, floating on the rod and held in place by springs with oil dropped on top of the rod for lubrication. Each engine has its own independent oil pump and filter supplying pressure lubrication continuously to bearings, crank and crosshead pins, and to main and intermediate crosshead slides. Sight-feed pumps supply cylinder oil to exhaust valve stems to piston rod packing, and through two inlets at each end of each cylinder so as to lubricate the cylinder thoroughly before each explosion stroke.

Mixture of constant quality is varied in amount according to the load by a spring-loaded governor which controls a relay valve in hydraulic balance, in turn controlling an oil-operated piston which actuates the mixing valves. Ports cut to 45 deg. give an effect similar to a cut-off valve.

Make and break ignition of 110-v. d.c. current actuates three spark plugs in each cylinder with induction coils to increase spark intensity.

Tests of the blowing units show 28 per cent thermal efficiency with gas having a dry thermal value of 105 B.t.u. per cu. ft. Cooling water takes 27.4 per cent of the heat; work, 28 per cent; unaccounted for, 7.9 per cent; and exhaust, 36.7 per cent, the exhaust gases being at 900 deg. F. and half of this heat being convertible in waste-heat boilers which generate low-pressure steam. Generator units show 143 cu. ft. of gas consumed per kilowatt hour with thermal efficiency of 28.6 per cent. Cooling water takes 28 per cent of the heat of the gas; work, 28.6 per cent; unaccounted for, 5.4 per cent, and exhaust gases, 38 per cent, these gases being at 1000 deg. F. and 6.5 per cent of the 50 per cent available for waste heat boilers being utilized.

Diesel Engines Raise Small Plant Efficiency

INDUSTRIAL PLANT OF FUTURE MUST SHOW ECONOMY COMPARABLE TO USE OF PURCHASED POWER. BY R. C. DEMARY

MANY engineers seem to be living in fear of the super-power central station. In fact, at a recent meeting an eminent engineer stated that the time was close when the small plant would be a thing of the past and advised those who were in charge of the so called small plants to prepare themselves for some other calling and advised the younger people to stay away from engineering.

This view seems too pessimistic. In the first place there will always be a demand for an up-to-date and efficient engineer, in the central stations if not in small industrial plants and in the second place the small plant will always be with us but instead of steam, Diesel or oil engines will probably be the prime movers.

Today there is hardly a manufacturer of steam engines who does not make an engine of the Diesel type and its future is certainly assured. The steam engineer who familiarizes himself with the care and operation of the Diesel engine need have no fear of the super-power central station.

It must be admitted that in stations of this kind the cost per unit output largely offsets the particular advantages that the Diesel has in fuel economy, but the great field for economy is not so much with the super-power plant as with the small or medium size plant.

The United States Department of the Interior has some interesting statistics showing that the average power plant in this country has a rated capacity of 200 hp. and that the average plant uses eight times as much fuel as the large central station per unit output. This being the case one can see that the great field for economy in the production of power is with the small plant, and the one prime mover that offers a simple solution in securing minimum production cost is the Diesel engine.

An investigation conducted by R. C. Burrus in the interest of economy, brought to light some startling figures, which are almost identical with those obtained by the author in a survey of 100 small plants operating in the City of Akron, O.

Usually the small plant is handicapped by a poor load factor and much less efficient equipment than the central station. It throws away heat through the steam pipes, ashpit, stack and engine. Out of every 2000 lb. of coal burned only about 125 lb. are actually utilized. This means that for every ton of fuel consumed under the boilers, 1875 lb. are absolutely wasted, the ratio being nearly 16 to 1.

To make this enormous waste more impressive let us look at it on a basis of dollars and cents. For every $10.00 that the average small plant invests in fuel about 60 cents worth is turned into mechanical energy and this means that $9.40 are wasted or thrown away never to be recovered. Measured from the coal pile to the bus bar this means an efficiency of about 6 per cent; certainly nothing of which to be very proud.

These losses are unknown where Diesel engines are used as this engine is a power unit complete within itself. It is a single unit in which the heat energy of the fuel is transformed into mechanical or electrical energy at the pulley. There are no standby heat losses. When the plant closes down at night or any other time no fuel is consumed. When power is needed the Diesel engine is ready to operate and is able to take up the full load in a few seconds.

In the accompanying table is given a comparison of costs taken from the records of a steam plant for ten months with a corresponding period after Diesel engines were installed, which is interesting.

Cost of Ten Months' Operation With Steam and Diesel Engine Operation

Plant	Costs			Suppls.	Total	Kw-Hr.	Cost per Kw-Hr.
	Fuel	Labor	Lubr.	Mant.	Cost	Output	Cents
Steam	22.368.22	9,335.56	441 31	655.31	32,801.39	709,190	4.69
Diesel	3,651 21	10,027.53	405.26	93.12	14,177.12	1,132,000	1.26

Saving 10 months with Diesel operated plant	$18,624.27
Percentage saving with Diesel plant	56.8
Increased load with Diesel plant	422,810
Percentage increase in load	59.6
Saving in cost per kw-hr. with Diesel plant	3.43c
Percentage saving with new plant	73.1

As service is continuous one engine is kept running 24 hr. a day for one week, the other serving as a spare unit or to handle a peak load. At the end of the week the other engine is placed in service for a similar length of time. During the fifteen months the Diesel plant has been in operation it has not been necessary to purchase a single repair part.

Cases similar to the above are being brought to light every day and are conclusive proof of the great future for this type of engine. The success, of all machinery however, depends upon how well it runs and performs the work for which it was intended and we know the engineer or operator plays an all important part. The best designs and workmanship in construction may count for nothing where intelligent care and operation are not provided. Here again we are confronted with that ever present "human element."

A steam engineer is the one who naturally takes up oil engine operation and if he makes mistakes at the beginning, through lack of knowledge, he should not be criticized too severely.

Many builders lead us to believe that their particular engine will work in the hands of any man and that no training is needed. This is all wrong and is bound to reflect on the builder in the end.

When the engineer who is used to steam takes up oil engine work he is confronted with an entirely different problem in operation. With fuel problems and boiler room troubles eliminated he is likely to underestimate the importance of others and think he has an easy job only to find himself mistaken.

No matter how dirty the fires under the boilers may be or how much fuel is burned the steam that reaches the engine will be clean and have a comparatively uniform temperature. If foul combustion is allowed in an oil engine a quick shut down is involuntary.

He has heat stresses, sticky and burned valves, fouled rings, worn cylinders, fouled lubrication and numerous other ills not found in a steam plant.

We must quit trying to fool ourselves about the work involved in keeping an oil engine as it should be. It is necessary for the operator not only to know what to do but also to do it. The oil engine is a self contained power plant and one which may be operated with little or no danger to life or limb.

The problems of Diesel engine operation are not so different from steam nor are they so difficult to understand but that any man with good common sense can master them just as easily as those presented by a steam operated plant. We do not need as an operator, a college professor, or a mechanical engineer for the oil engine is no mystery.

Start to prepare yourself to handle the Diesel engine, for there is a crying need for good Diesel engineers.

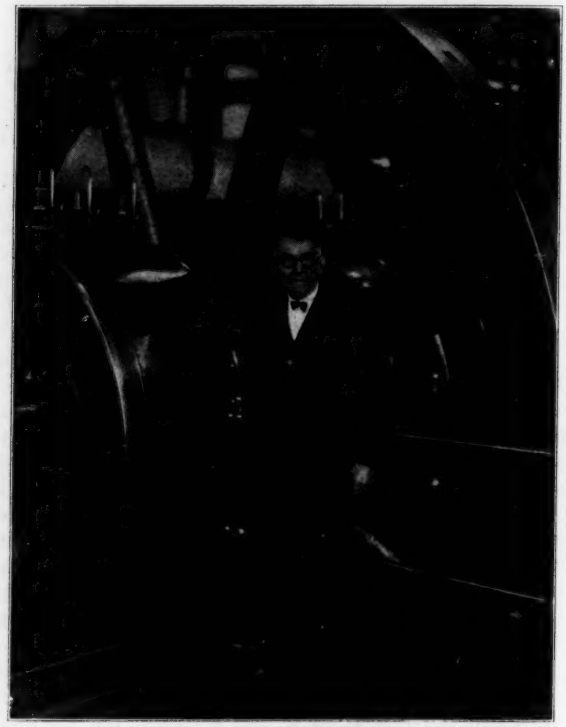
IN THE CONSTRUCTION of additional power plant capacity at Long Beach, the Southern California Edison Co. is speeding up the foundation work to a great extent by the use of salt water at 250 lb. pressure for the purpose of jetting in the piling. This high pressure water is furnished by the 10-in. tandem multi-stage motor driven turbine pump, which equipment is a permanent portion of the installation provided for the purpose of removing the barnacles and other tenacious sea growth from the interior surfaces of the concrete intake tunnels of the circulating water system.

Engineer Establishes Service Record

By H. S. McKENNEY*

TO THE MOST of us, 57 yr. on one job seems like a long, long time, but to Elden Guptil the years have passed by lightly and now at 78 yr. of age he seems as active as when I first met him 24 yr. ago, when I was one of a crew erecting engines at his plant. One of these same engines is shown in the background of the photograph of Mr. Guptil, recently taken.

This remarkable old man is power engineer at the Diamond Match Co., at Biddleford, Maine, where he has been employed continuously for 57 yr., although the plant has changed hands several times. He was born March 4, 1848, at Waldo, Maine, and when 18 yr. old became a fireman for a paper company. In 1869, at the age of 21, he went to the same plant where he is today.



Mr. Guptil, in spite of his advanced age, is in excellent health and is quite active. When outdoors his recreation is automobiling and when he cannot leave the house he amuses himself by playing the organ.

His early education was meager, but he reads a great deal and is well versed in all the modern appliances used in power plant engineering. He thinks that all boys should have a high school education and then learn a trade, provided they cannot go to college.

His family consists of a wife, three sons, a daughter and a granddaughter.

He does not use liquor or tobacco, attends church when he can and is an ardent Bible student. He has a good word for everybody, is loyal to his employers and is always in a jovial frame of mind. He says if he had his life to live over again he still would want to be an engineer.

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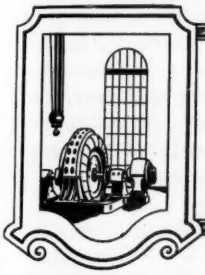

ELECTRICAL MACHINERY FOR LIGHT AND POWER

Theory of Generator Action and Use of Interpoles

PRINCIPLES OF ELECTRO-MAGNETIC INDUCTION IN GENERATORS AND MOTORS. CAUSES OF SPARKING AND METHODS OF PREVENTION. BY CHARLES G. GREEN*

IT IS fairly well understood that when a conductor is passed through a magnetic field so as to cut lines of magnetic force, an electromotive force (voltage) will be generated in this conductor. A permanent magnet of the horseshoe type, shown in Fig. 1A, with the polarity as indicated has, in the conventional sense, magnetic flux leaving the north and entering the south pole. If a conductor is placed at one side of the magnetic field, as indicated, and by the power of a steam engine, gasoline engine, waterwheel, or other prime mover, this conductor is forced across the magnetic flux, as indicated by the arrow, a voltage will be generated in it which according to Flemming's rule will be in the direction indicated by + or in from the observer. Now, if the ends of this conductor are connected as shown in Fig. 1B, through a lamp or motor, there will be current forced through in the same direction.

Flemming's rule for generators was given in a recent issue of this magazine in an article on synchronous motors,

FIG. 1. SHOWING HOW A VOLTAGE IS INDUCED IN A CONDUCTOR MOVING IN A MAGNETIC FIELD

but to have it handy, it is repeated here. Place the thumb, first finger and remaining fingers of the right hand at right angles. Let the thumb point in the direction the conductor is being moved, and the first finger in the direction of flux, or from the N. to S. pole; the remaining fingers will then point in the direction of the induced voltage, which is generated in the conductor.

When we connect the external circuit and under the action of the voltage we allow electricity to flow, there will be a flux around the conductor in a clockwise direction at all times, if the observer is looking in the direction of current. To remember this the following rule is useful: Grasp the conductor with the right hand, and let the thumb point in the direction of current. The fingers will then point in the direction of the magnetic whirl or field.

If the current is in the direction indicated in Fig. 1A, there will be a flux around this conductor in the direction indicated in Fig. 2.

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Now it must be understood that with lines of force traveling in the same direction, there will be a repulsion which will try to crowd the two fluxes away from each other, and, in this case, the flux around the conductor will repel the flux from the field poles. This repelling force

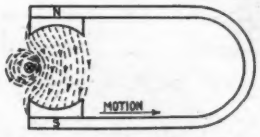


FIG. 2. REACTION BETWEEN THE MAGNETIC FIELD DUE TO CURRENT IN THE CONDUCTOR AND THE FIELD IN WHICH IT MOVES

will always tend to move the conductor in a direction opposite to the motion of the conductor.

From this it can be seen that the more current we have flowing through the armature conductor, the greater will be the flux around it, and, as the amount of flux determines the amount of attraction or repulsion of magnets the greater will be the repulsion between the armature and field of the elementary generator in Fig. 2, thus putting more load on the mechanical device acting as the prime mover.

If we arrange several conductors so the voltage of each one will add to the voltage of the next till we have a high voltage generated, we can then force considerable current through the external circuit enabling it to run motors and light lamps. A great number of methods are in use for connecting these various conductors in series, so as to secure the voltage desired. Several methods employed at one time have been done away with as inefficient or too expensive.

The old type ring wound armature, being an easy one to explain but hard and expensive to wind and also inefficient in operation, is now given very little attention except in elementary books. However, a brief explanation may aid in understanding some of the more modern types of armatures.

As shown in Fig. 3 it consists of an iron ring built up of laminations or thin sheets of soft iron provided with a winding. A cross section of this ring is shown in Fig. 4 with the slots and location of coils partly shown. It will be apparent that the only part of the coil which is generating voltage is the side in the slot, which is the side near the pole face in Fig. 3.

If now the armature is rotated in the direction indi-

cated a voltage is generated in all conductors which are under the pole faces. On one side as at A it will be generated as indicated by the small circles representing the ends of a few conductors, if they were cut off at that point, and on the opposite side as indicated by the circle with the "X."

Connecting the external circuit from positive brush + to negative brush — through a suitable resistance, such as a motor or lamp, will result in a current from the positive brush to the negative brush on the outside and from the negative to the positive inside of the armature wires, as indicated by the small arrow points on the wires. Notice that the coils will all be in series on each side but the two sides will be independent of each other. Also, that while voltage is generated only in the side of the coil near the

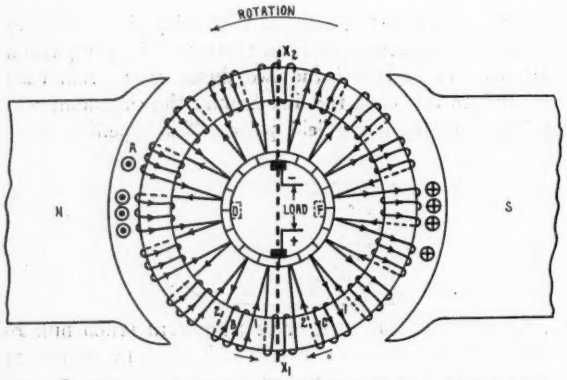


FIG. 3. SIMPLE DIAGRAM OF A RING WOUND ARMATURE

pole face the current which passes from coil to coil must pass through a dead part of the coil. This inactive portion of the wire not only increases the total resistance for a machine of given voltage, but also increases considerably the amount of copper required for a given size machine.

Commutator is a Mechanical Rectifier

A commutator is often regarded as a mechanical rectifier, changing alternating current to direct current. This can be understood readily by noting the action of the coil near the brush, Fig. 3. Imagine this coil as rotating and remember that, as shown, the coils under a north pole have a voltage and current in one direction, while those under an opposite pole will have current and voltage in an opposite direction. When a coil is at B, Fig. 3, the direction of current, or direction of voltage acting will be as shown by the short arrow which points toward the side of the coil connecting to a commutator segment supporting the brush or, in this case, half of the brush. Now let this coil move over one position to X_1 and it becomes shorted by the brush. There should be no current flowing in it at this point because the coil next to it has come around far enough to make contact with the brush. Now let the shorted coil move on from this position and it will be in a position marked C, with its opposite end connected to the brush. First, we had end 1 of coil B feeding the brush and now when B has moved over to C the current in the coil has reversed due to its coming into the field of an opposite pole. It must be noted, however, that the connections to the brush have also reversed and instead of end 1 being connected to the brush we have end 2, which, as can be seen, feeds the current to the brush in the same direction. The brush always receives current from the two coils at the same time. The same action takes place at the negative brush, except that the brush is feeding the coils. It can be seen, then, that even though there is an alternating current in the coils, the brushes being stationary, while the coils and commutator segments move, the current sent from the brush to the external circuit is always in the same direction, that is, it is what is known as direct current.

Placing the Brushes

We have two reasons for placing the brushes in the so-called neutral plane, as X_1 and X_2, Fig. 3. First, with this brush setting all the coils with voltage generated in one direction will be adding to produce a high voltage, that is, the individual voltages induced in all the coils between X_1 and X_2 in either direction will be added while if the brushes were shifted over to a point D and F, the voltage in one-half of the coils on one side would act in one direction and the other half in an opposite direction, resulting in zero voltage. The nearer the brushes are to the position where all coils on one side have the same direction of voltage, the higher will be the resulting voltage, until at neutral plane the voltage will be the highest.

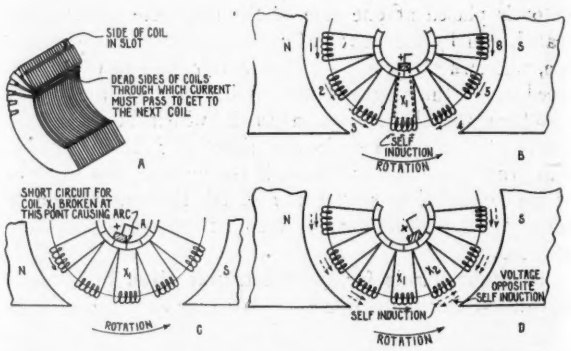


FIG. 4. A. SECTION OF RING ARMATURE SHOWN IN FIG. 3. B. SHOWING CURRENT DUE TO SELF INDUCTION IN COIL SHORT CIRCUITED BY BRUSH. C. ARC FORMS WHERE BRUSH LEAVES COMMUTATOR SEGMENT. D. SHOWING EFFECT OF BRUSH DISPLACEMENT

A second reason for setting the brushes in this or near this neutral point is that each brush, as can be seen in Fig. 3, is short circuiting a coil and if the voltage induced in this coil was high, when it was shorted there would be a large current through the coil itself resulting in sparking at the brushes and undue heating of the coil.

Shifting the Brushes

As current passes through a wire or coil of wire, a magnetic flux is built up around it. If the current is broken and the flux decreases to zero, in decreasing it cuts across the wires of the coil and generates a voltage in them. As the flux expands with an increase of current the voltage induced is in one direction, as it contracts due to a decrease in current, the induced voltage is in another direction. This voltage is called the "self-induced voltage." If in a certain coil, a field coil say, there are a large number of turns of wire, the flux due to each turn of wire in the coil, cutting across all the other turns of the coil, will generate a voltage of considerable magnitude. In other words the voltage of self induction is directly proportional to the number of turns. Even, in coils of few turns, how-

ever, where the induced voltage is low, there may be considerable current if the coil is short-circuited, as is the case with a coil under a brush.

The effect of self-induction is always to produce a voltage, which tends to keep current flowing when it is broken and which tends to oppose it when it is started.

Now if we break a circuit to shut off the current, the self-induction will cause an arc to occur at the point where the circuit is broken; the more self-induction, the longer the arc.

Referring to Fig. 4A, which is a small section of the armature of Fig. 3, we find that coil X_1 in Fig. 4B, is the one short-circuited by the brush. The current through the coils is as indicated by small arrows 1-2-3. Now, when a coil moves into the neutral plane and becomes short-circuited by the brush, permitting the current to flow direct through the brush without passing through the coil, the flux around the coil will die down and generate a voltage (self-induced) which, as stated before, will for a short time, force current through the coil in the same direction it was flowing. This is indicated by the small dotted arrows through the coil.

As long as this brush is short-circuiting the coil no real damage is done. With the machine rotating at high speed, however, these commutator segments move out from under the brush before the self-induced voltage has decreased to zero and when the edge of the segments leaves the edge of the brush as at A, Fig. 4C, there will be a flash or arc, due

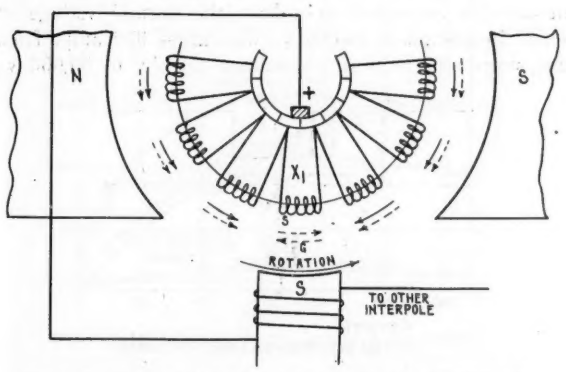


FIG. 5. DIAGRAM SHOWING THE USE OF INTERPOLES

to breaking a circuit that had current flowing in it. This will cause an arc as indicated by arrow. The action is repeated as each segment leaves the brush.

To eliminate the sparking caused by self-induction we may "shift the brushes in the direction of rotation" and allow the coil to have a little reversed voltage generated in it as at X_2, Fig. 4D. By letting the dotted arrows indicate the voltage generated and the full arrows the current, we find the coil X_1, which in Fig. 4B was short-circuited by the brush, is now (Fig. 4D) acting only as a conductor to carry the current from the coils which are generating useful voltage to the brush while the coil X_2 which has the brush short-circuiting its two ends is also under the influence of a south pole and generating voltage which is opposite to that of self-induction.

If the brushes are properly set these opposed voltages in the coil shorted by the brush should be equal, resulting in zero current. Since there is no current no arc will occur when the segment moves out from under the brush.

If the brush is shifted too far, so as to be under the influence of a stronger field, the voltage generated in the shorted coil will be more than enough to neutralize that of self-induction and a current will pass through the coil in an opposite direction, producing an arc in the same manner as before.

It can be seen that if we increase the load on the generator the flux around the conductors will be increased accordingly and the induced voltage caused by this flux dying down when the brush shorts the coil will also be increased. We must, therefore, shift the brush farther in the direction of rotation, so as to short a coil which has a sufficient voltage generated to neutralize the voltage due to self-induction.

This, however, is hard to do, especially when the load is of a variable nature. In this case we must set the

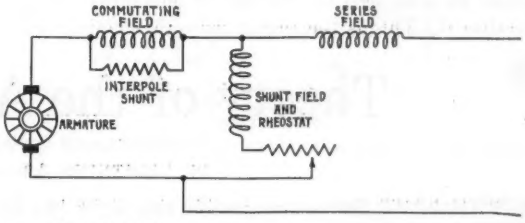


FIG. 6. WIRING DIAGRAM OF INTERPOLE MACHINE

brushes for an average load and let them spark at heavy load and also at light load, but at the average load or the normal load, we can obtain fair commutation. To improve commutation, brushes are also designed so as to have a certain contact drop, or, in other words, to have sufficient resistance, to prevent the self-induced voltage from forcing excessive current through them.

In a low voltage machine, such as an automobile generator, there are fewer turns of wire in each coil, consequently there is less self-induction. Here we can even use copper brushes in place of the carbon.

Assuming a constant speed the higher the voltage of the generator, the more turns of wire must be put in each coil, and the greater the self-induction; also the higher must be the resistance of the brush to help in limiting the current through the shorted coil.

Taking all this into consideration, it is plain to see why some shops and plants have trouble with their commutators of d.c. motors, generators and rotary converters. After the machine is run for some time and it is necessary to renew brushes, the maintenance man reaches up on the shelf or, sometimes, in the box of discarded brushes, takes either a piece of new common carbon or an old brush that still has enough material left to saw a brush out for a small machine and uses it, whether it possesses the proper requirement for his machine or not.

Again he may put the brush of the proper nature in the machine, but due to the application of too much pressure it allows an excessive amount of current to pass, resulting in severe sparking.

Action of Interpoles

Let us refer back to Fig. 4B and see how the self-induction occurs and then to Fig. 4C showing the arc. Note that by letting the coil pass on under an opposite pole, as Fig. 4D, before we short it, there is a voltage generated opposite self-induction and will neutralize and prevent the arc from occurring.

Now refer to Fig. 5, where it will be noted a small magnetic pole is placed between the main poles. By making it the same polarity as the pole toward which we shifted the brushes, before having interpoles, we should be and are able to generate in the shorted coil a voltage shown by dotted lines at coil X_1 and indicated by dotted arrow G, which is opposite the self-induced voltage indicated by dotted arrow S. The other dotted arrows represent voltage generated by other coils and the full arrows the current. Notice that there will be no current in the short-circuited coil X_1.

If the interpole should have its winding connected so as to produce a north pole in this case the two voltages would both add to produce bad sparking at the brush.

If we increase the load, or rather the current, through the armature, thus increasing the voltage due to self-induction, we also need an increase of generated voltage to neutralize it. This is the reason why all windings on the interpoles, commonly known as the commutating winding, must be connected in series with the armature as in Fig. 5. Any increase of current producing high voltages of self-induction will also increase the strength of the interpole and increase the voltage generated to neutralize that of self-induction. The commutating fields should always be connected so as to have the same polarity as the next main pole in the direction of rotation for a generator and opposite for a motor.

There should be nothing tapped on between the commutating field and brushes or armature and if the interpoles are properly connected and their strength properly adjusted by the interpole shunt, if the machine has one, or if it is a small one, by shifting the brushes slightly, they will always bear the correct relation to the main poles for any rotation or direction of voltage generated. Figure 6 shows the interpole shunt as used with some large generators.

Theory of the Autovalve Arrester*

PRINCIPLES OF OPERATION OF THE VALVE TYPE OF LIGHTNING ARRESTER. BY JOSEPH SLEPIAN

IN THE LAST few years, considerable light has been shed on the manner of induction of high voltage on power systems by lightning, and some estimates of the magnitudes involved have been made. Charges on clouds produce electrostatic fields extending down to the ground, which induce charges on power lines. The vertical gradient at the earth's surface due to these fields has been estimated to be of the order of 100 kv. per ft. When the inducing charges on the clouds disappear suddenly by a lightning discharge, the induced charges on the power lines produce voltages to ground equal to the height of the lines multiplied by the inducing gradient and, therefore, of the order of hundreds of kilovolts. The induced charges may be a few miles in extent.

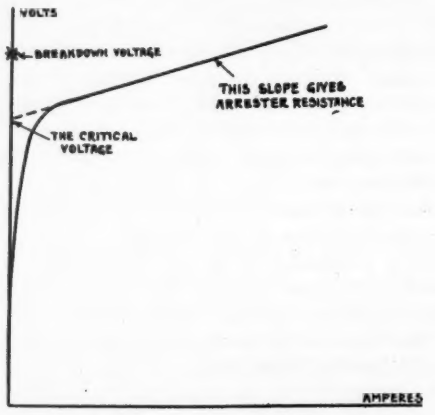


FIG. 1. THE VALVE CHARACTERISTIC

ENERGETICS OF SURGE DISSIPATION

The large current which must pass through an arrester, if it is to be really effective, introduces great difficulties in the design of arresters of the arc-resistance type for higher voltage circuits. This is not due to the energy of the surge itself, which is only moderate in amount because of its short duration, but to the energy supplied by the normal working voltage, which lasts throughout the whole arcing period, and may be from one-half cycle to several seconds. For example, a surge 1.86 mi. long will discharge for only 1/100,000 sec. If an arrester connected to a line, the normal voltage of which to ground is 10,000 v., discharges 900 amp. from this surge and reduces the voltage thereby to 30,000 v.,

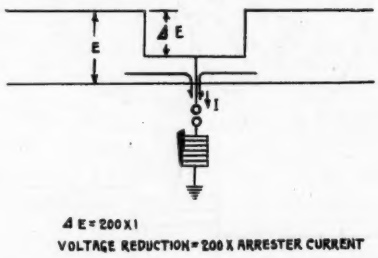


FIG. 2. BASIS OF CALCULATION OF FIG. 3

the energy involved will be only 30,000 by 900 by 1/100,000, or 280 watt-seconds. On the other hand, if the normal line voltage discharges 30 amp. for one-half cycle, or 0.0083 second the energy will be 10,000 by 300 by 0.0083, or 24,900 watt-seconds or more than 90 times the energy due to the surge alone.

Valve type arresters, being built up of elements having the characteristic shown in Fig. 1, are not subject to the disadvantage of disposing of this large draft of energy from the normal voltage. With the passing of the surge, and the restoring of normal voltage, the discharge ceases.

Some illuminating calculations made for an arrester set at the center of a freed charge as shown in Fig. 2 are given in the curves of Fig. 3. The initial surge voltage is taken as 250 kv. The normal voltage to ground is taken to be 8660 v. and the line surge impedance, 400 ohms. The heavy line curves show the reduction in voltage for carrying resistance in an arrester of the arc type and one of the valve type with critical voltage, 10,000 v. Evi-

*Abstract of a paper delivered at the Midwinter Convention of the A. I. E. E., New York, N. Y.

dently suitable protection is not obtained until the arrester resistance is less than 50 ohms.

The light lines show the energy dissipated in the arrester. In order to get the curve for the valve type well into the picture, it is necessary to consider a surge 400 mi. long; the more reasonable surge length, 4 mi. would be barely visible on the scale chosen.

Modern Valve Types

The so-called valve characteristic, shown in Fig. 1, has been frequently discussed, and the terminology indicated in the figure is generally used. Conducting systems having this characteristic are numerous in nature; however, in most of these systems, the critical voltage is too low (as in contacts or electrolytic polarization cells), or the current which may be carried is too small (as in thermionic or low pressure gas tubes), to be useful for lightning arresters for power lines. So far, the only systems which have been found to possess the valve characteristic to a necessary degree have been certain films which are made conducting by application of sufficient voltage, but which are subject to constant repair action, requiring the continued application of the high voltage for the maintenance of the conductivity and in which the

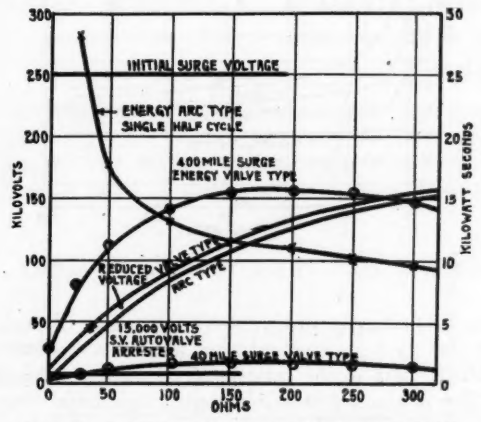


FIG. 3. ENERGETICS OF SURGE DISSIPATION

original resistivity is restored when the voltage is reduced. Three practically used arresters have been developed utilizing films of this type—the electrolytic, the Oxide Film, and the Autovalve arrester.

In the Autovalve arrester the film is a thin layer of air next to a cold cathode which is the seat of the cathode drop in a glow discharge. With the application of sufficient voltage, this air film becomes highly ionized, but the discharge of these ions into the electrodes and recombination quickly restore the normal resistivity when the voltage is reduced.

The Breakdown of Air Between Parallel Plane Electrodes

Since the active element in the autovalve arrester is air, any explanation of the arrester's design and functioning must include a discussion of the properties of air with respect to electrical breakdown and resulting conductivity. Figure 4 shows the relation between breakdown voltage and distance between parallel plane electrodes. A striking feature of this curve is the minimum at electrode separation of 0.001 cm., so that shorter separation than this requires increased voltage for breakdown. This remarkable fact is readily explained by the current theory of ionization by collision.

The existence of a minimum breakdown potential of about 350 v. for short gaps may seem contradictory to experience. For example, a widely used type of telephone protector consisting of two small carbon blocks separated by 0.002 in. will usually break down at 200 v., or sometimes even less. In this case, however, the breakdown is due to the lining up of carbon dust particles in the intense electric field so that a conducting bridge which

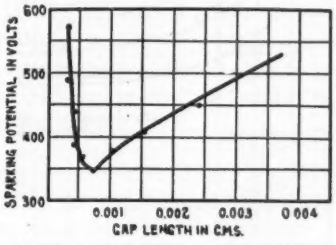


FIG. 4. SPARKING POTENTIAL FOR SHORT AIR GAPS

starts an arc is formed. If precautions are taken to prevent contacts taking place in this or any other manner, the existence of a minimum breakdown voltage may be shown experimentally.

In the autovalve arrester, it is necessary to use gaps between resistance material electrodes with a breakdown voltage of little more than 350 v. The curve of Fig. 4 indicates that an electrode separation of 0.0003 in. is necessary for this. At first sight, so minute an electrode separation would appear impracticable in a commercial arrester.

This difficulty was overcome in the early experimental autovalve arresters by merely placing the resistance electrode disks in contact. Due to the resistivity of the electrode material, the gap would not be short-circuited at

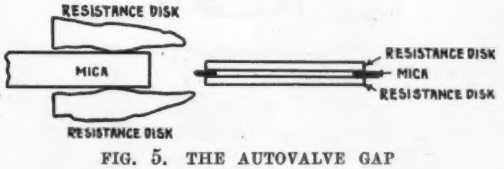


FIG. 5. THE AUTOVALVE GAP

the contacts. At the same time, in the neighborhood of each contact there would be points at which the electrode separation was 0.003 in. and there breakdown at 350 v. would occur.

A better solution now used was found later and consists in using a mica spacer, 0.003 to 0.005 in. thick, placed directly between the disks. Figure 5 shows the standard autovalve element (right) and section at the mica spacer, highly magnified (left). The mica, having a dielectric constant of six to seven, distorts the electrostatic field very much as if it were conducting. Thus, there is a concentration of electrostatic stress at the corners of the mica. Due to inherent variations in the nature of the surface of the resistance disk and its contact with the mica spacer the total voltage applied is not expended symmetrically between the two disks and the edges of the mica, but at some points nearby, all the voltage appears between one resistance disk and the adjacent mica

edge and at other points between the other resistance disk and adjacent edge. Hence when a little more than 350 v. is applied, these highly stressed points break down and precipitate the discharge of the whole gap. Numerous tests have shown that in commercial autovalve arresters, the breakdown of the column of disks is less than 400 v. per gap.

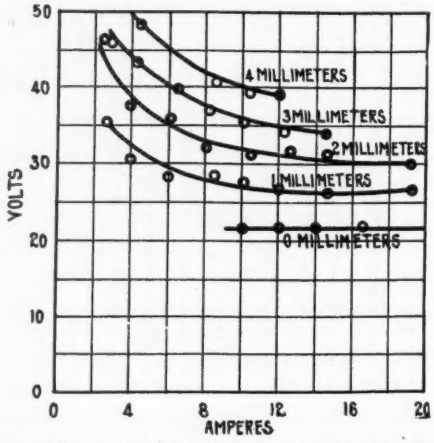


FIG. 6. ARC CHARACTERISTICS FOR COPPER

This expedient of using the electrostatic influence of the mica spacer to precipitate the discharge at low voltage is not practically useful if metal electrodes are used. The discharge must start at the mica, and if it is permitted to concentrate at its point of origin as with metal electrodes, the mica is quickly destroyed. In the auto-

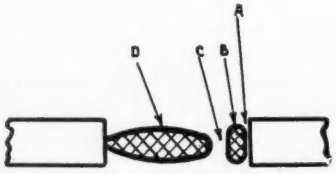


FIG. 7. THE GLOW DISCHARGE (MAGNIFIED)

valve arrester, relatively high resistivity electrodes are used, which limit the intensity of the discharge next to the mica. Hence, thousands of discharges may be sent through it with no deterioration of the mica.

Electric Discharges in Air

Arc Discharge. The breakdown of a gap is due to the ionization produced by the high electrostatic gradient. If the gap is to remain conducting for the duration of a discharge, this ionization must somehow be maintained. If the cathode remains cold the ionization is effected by the field becoming so distorted that with carbon electrodes, approximately 350 v. are impressed across a layer of air 0.001 cm. thick next to the cathode. The discharge then takes the form of a glow. If, however, the cathode becomes sufficiently hot for thermionic emission, much less voltage need be expended at the cathode and the discharge takes the form of an arc.

In the arc discharge the voltage expended at the cathode must be sufficiently great to maintain the cathode at a temperature sufficiently high for thermionic emission, and also must be sufficiently small space next to the cathode so that the electrons liberated thermionically will ionize by collision. Twenty volts are sufficient for both these purposes for most electrode materials.

In addition to the voltage expended at the cathode, some must be expended in carrying current in the remainder of the discharge. This additional voltage is found to vary inversely as the current strength, so that characteristics such as shown in Fig. 6 are obtained.

It is now clear why an arc discharge is not suitable for giving the valve characteristic to a gap. Aside from the melting or burning of the cathode due to its necessary high temperature, the voltage of the arc discharge is too low (about 20 v. for short gaps), in comparison with the lowest reliable gap breakdown of about 350 v.

Glow Discharge

When the cathode is too cold for thermionic emission, the glow form of discharge takes place in which the ion-

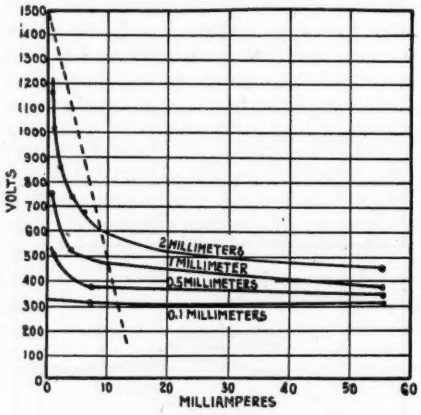


FIG. 8. GLOW CHARACTERISTICS FOR COPPER

ization is primarily produced by ionization through collision due to high gradient in a film of air about 0.001 cm. thick, next to the cathode. The voltage expended in this film is about 350 v. for carbon electrodes. Figure 7 shows on a magnified scale the appearance of such a glow between copper electrodes. This was obtained by reducing the current to a few milliamperes by means of a high series resistance. When the current is so small, the heating of the cathode is insufficient for an arc and so the glow discharge may be maintained indefinitely. A, the cathode dark space, is the 0.003-in. film which is kept broken down by the high gradient due to the 300 v. (cathode drop for copper) across it; B, the cathode glow is a highly ionized blue region, about 0.005 in. thick. C, the Faraday dark space, is also highly conducting and is about 0.010 in. thick. D, the pink positive column, extends to the anode.

So long as the cathode is not completely covered by the discharge the cathode drop and the cathode current density are approximately independent of current, the cathode glow simply increasing or decreasing in area as the current is varied. The cathode drop and current density to vary with the nature of the cathode; for carbon, the cathode drop and current density are respectively about 350 v., and 10 amp. per cm.

When the cathode is completely covered by glow, further increase of current must, of course, increase the current density. An increase of current density causes a mod-

erate increase in the cathode drop. Extrapolation of a theoretical formula shows that an increase in current density of 25 amp. per sq. cm. increases the cathode drop by 37½ v.

The conductivity of the blue glow and the Faraday dark space is so great that little voltage is consumed in these parts. In the pink column, however, the resistivity is greater, and for small currents, the gradient in it may amount to over 5000 v. per cm.; however, this gradient decreases, as the current increases.

Volt-ampere characteristics of a glow between copper electrodes are shown in Fig. 8. The longer gap lengths show a falling characteristic due to the properties of the pink positive column. For the 0.1 mm. gap, the positive column is completely eliminated and so a flat characteristic is obtained.

Design of Autovalve Arrester

The three essential parameters in the autovalve arrester element, which determine its electrical performance, are gap length, electrode resistivity, and electrode area. A desirable characteristic is a discharge voltage only little less than the breakdown voltage and this with a minimum of resistivity in the electrode material so that impractically large area will not be necessary for adequate discharge capacity.

From Fig. 8, it would appear that if the current density is sufficiently limited, a discharge voltage nearly equal to the breakdown voltage may be obtained. Thus, the valve characteristic may be obtained for any gap length if only electrodes of sufficient high resistivity are used.

With gap lengths less than 0.015 in., the resistivity of the electrode material must be made only high enough to take care of surface inhomogenetics and the partial contacts due to bridging particles. These are not calculable and the permissible low limit resistivity must be determined by test. The low limit for resistivity in commercial autovalve arresters at present is 20 ohms per cm., giving a total resistance of only a fraction of an ohm per disk.

The gap length and resistivity being thus given, the area of the electrodes will determine the discharge rate of the arrester. In the SV type of autovalve arrester, the area has been chosen to give a discharge rate equal to that of the electrolytic arrester.

Shop Power Plant Shows Economical Operation

New Plant of Sullivan Machinery Co. Generates Cheap Power with Uniflow Engines

COMPRESSED AIR, an agent so vital to many industrial engineers, which has made possible our huge skyscrapers, our tunnels and subways, and daily meets many other needs in shops, is better appreciated after a visit to the plant, about 3 mi. southeast of Michigan City, Ind., which the Sullivan Machinery Co. has erected for the manufacture of air compressors, air drills, coal cutters and other machinery for mining, quarrying and tunneling. This plant is located on a tract of 120 acres giving plenty of room to expand.

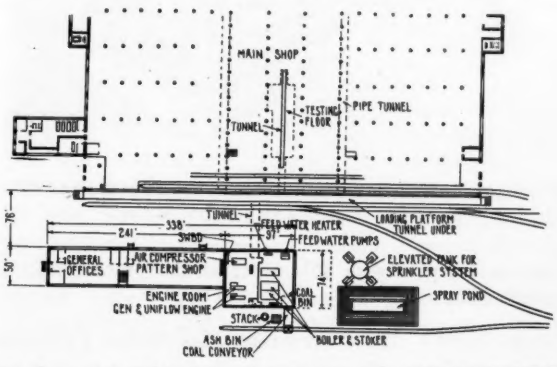


FIG. 1. PLAN OF POWER HOUSE AND RELATED EQUIPMENT

To users of power, the method of power generation and distribution in this plant provides several interesting features. A plan view of the first group of buildings, Fig. 1, shows the general offices and pattern shop, with the engine and boiler rooms at the rear, covering a space 74 by 97 ft. Behind the boiler room is shown a 75,000-gal. steel tank on a 100-ft. tower used for the distribution of water to the sprinkler system. To one side of this tank is a concrete spray pond, 115 by 50 ft. and 4 ft. deep, for cooling the condensing water, with spray nozzles supplied by the Binks Spray Equipment Co.

As shown in Fig. 1, a switch from the railroad running to the north of the power house permits coal to be dumped directly from cars into a track hopper. Thence it is carried by a conveyor to a crusher and then elevated to an overhead 200-t. bunker. An electrically operated weighing larry of 1-t. capacity, hand controlled by ropes from the floor, distributes the coal from the bunker to the stoker hoppers. All coal handling equipment was furnished by the Jeffrey Mfg. Co., with the exception of the weighing larry which is a product of the Standard Scale and Supply Corp.

FIG. 2. COAL IS HANDLED BY CATERPILLAR TRACTOR OR DUMPED FROM CARS TO TRACK HOPPER. TOP OF HOIST IS SHOWN ABOVE STORAGE BUNKER

An outside view of the boiler room is shown in Fig. 2, with a coal car placed over the track hopper where it may either be dumped into the hopper or unloaded by a caterpillar tractor crane into yard storage, the usual yard stock being about 1200 t. This caterpillar crane is also used for handling the coal directly from yard storage to the track hopper. After the coal passes through a single-roll Jeffrey crusher, located in the low frame building directly to the right of the car, where it is crushed to 1¼-in. size, it is elevated above the bunker by a conveyor on the outside of the building as shown in Fig. 2, and is distributed to the bunker by two spouts. Near the base of the stack may be seen the concrete ash bin into which the

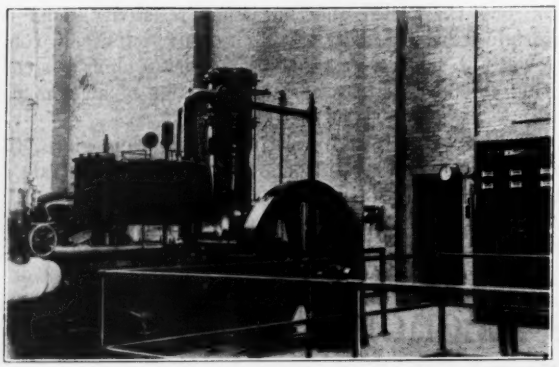


FIG. 3. FLYWHEEL SIDE OF SULLIVAN WD AIR COMPRESSOR

ash from the stokers is discharged by means of steam-jet ash conveyors, supplied by the Conveyors Corp. of America, while swinging spouts provide means of discharging the ash from the bin into a car.

Description of Boiler Room

Steam is generated by three 250-hp. vertical boilers operated at 200 lb. pressure. Two of these boilers are in battery and the third has a single setting, all furnished by the Wickes Boiler Co. The coal is burned on three 6- by 9-ft. Green natural draft chain grate stokers, driven by a small Wachs vertical steam engine, stokers and engines being supplied by the Combustion Engineering Corp. The boilers are equipped with soot blowers, manufactured by the Vulcan Soot Cleaner Co.

Hovalco blowoff valves are installed by the Homestead Valve Mfg. Co. and the boilers are blown into a 48- by 60-in. blowoff tank. Practically all other valves on steam, water and air lines were furnished by Crane Co.

The speed of the stoker engine and the draft at the flue dampers is controlled by differential pressure regulators supplied by the Ruggles-Klingemann Mfg. Co.

Feed water to the boilers is supplied by two 10 by 6 by 12 in., outside end packed duplex pumps manufactured by Dean Bros. Co. Copes feed water regulators were furnished by the Northern Equipment Co. and the water is heated in a 1500-hp. open heater equipped with a V-notch meter, supplied by the Cochrane Corp.

Water supply to the heater comes from a 54-in. by 12-ft. vented receiving tank located over the top of the heater, with flow to the heater regulated by a float-controlled valve. The general water supply to the tank comes from the heating system and surface condenser and the make-up water from a 3-in. city water connection. The water level in the tank is maintained by a 2-in. float-operated balanced valve. There is also direct connection from this overhead tank to the pump suction, thus bypassing the heater and connection direct from the city water main to the pump suction, bypassing the tank.

Two Simplex Worthington vacuum pumps serve the heating system; one, 7 by 12 by 12 in. is used for the factory system and the other, 4½ by 6½ by 6 in., is used for the office.

Uniflow Engines Show Economy

Passing from the boiler room to the engine room, a 10-in. header from the boilers supplies steam to two 21- by 24-in. uniflow engines, built by the Ames Iron Works, direct connected to two 312-kv.a., 3-phase, 60-cycle, 440-v. General Electric generators. These engines have vindicated the judgment of the plant designers showing a water rate of about 14 lb. per i.hp.-hr. when running condensing, while the actual cost of producing a kilowatt hour is such that any power purchased from an outside source would have to cost less than 1 cent per kw-hr. in

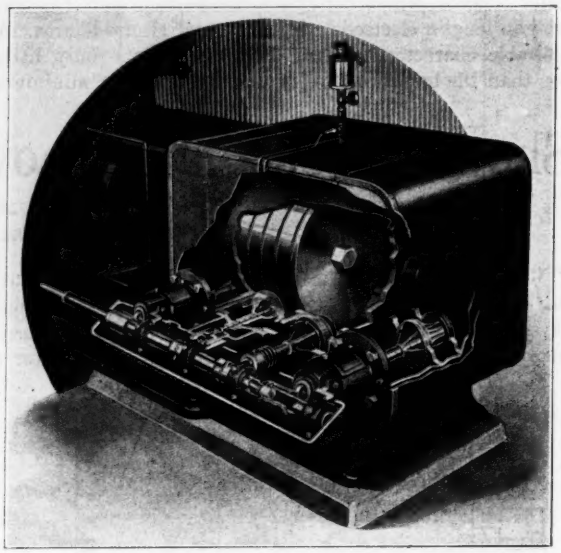


FIG. 4. CUT-AWAY VIEW OF COMPRESSOR STEAM CYLINDER, SHOWING VALVE AND PISTON ACTION

order to compete with this plant at the present rate of consumption.

Steam Driven Air Compressor Has Novel Features

In addition to the uniflow engines, steam is supplied to a 20 and 20 by 12 by 14-in. type WD Sullivan two-stage air compressor shown in Fig. 3. This machine is representative of the leading product of manufacture of the Sullivan Machinery Co. and has a slightly lower water rate than the uniflow engines, when running condensing. It has a net air piston displacement of 1100 cu. ft. of free air per min. at 225 r.p.m. and supplies compressed air at 100 lb. per sq. in. to all parts of the plant. Its low-pressure cylinder is horizontal and the high pressure cylinder is vertical, a single, high-duty steam cylinder being placed in the rear of and tandem with the low-pressure air cylinder.

This steam cylinder as shown in Fig. 4, is of a direct-flow, four-valve pattern, in which the steam travels in a direct path, the exhaust control and the proportioning of compression being such as to avoid heat losses due to ini-

tial condensation. The cylinder casting contains the exhaust ports, placed near the bottom of the bore and at some distance from the cylinder ends. The cylinder head contains the steam ports, in which the steam valve cages are pressed. The entire head is utilized as a reservoir for the steam, so that the head temperature will be the same as that of the steam entering the cylinder. The admission ports are placed at the bottom of the heads and extend below the bore of the cylinder to permit any condensation, entrapped after the exhaust valves have closed, to escape into the head.

The steam and exhaust valves are of the Sullivan "wafer" types, consisting of flat rings of thin tempered alloy steel. Each of the steam valves, as shown in Fig. 5, is supported by a four-arm spider and a removable seat. The seat is pressed into the cylinder head and the valve is held against the seat by a coil spring on the end of the valve steam. This grooved stem is a ground fit for the bore in the valve cage, making a labyrinth packing, so that no separate valve steam packing is required. In operation, each steam valve is raised from its seat by a cam acting on a roller on the outer end of the valve stem. Steam is admitted around the outer edge of the valve and through its center. There is no hammering action on the valve seats, owing to the lightness of the valve and to the fact that the roller is in contact with the cam at all times, so that the valve cannot move to its seat more rapidly than the cam permits. Steam entering the cylinder heads from the boilers is on top of the valves at all times, thus keeping the valves tight on their seats when they are closed.

Behind the valve, Fig. 5, is a coil spring which serves as a cushion at the end of the stroke. When the valve stem is at rest, the valve itself may be raised from its seat by compression or by a slug of water and will be returned to its seat by the relief spring, without disturbing the relative positions of the roller and cam. This arrangement allows for the necessary variation of the ratio of compression with variation in steam pressure. The steam valves and valve stems may be removed through the back bonnets, without disturbing the bonnets or valve gear.

Two exhaust valves are similar to the admission valves but with the relief spring omitted. The exhaust valve cages are loose in the cylinder, having a ground shoulder fitting a similar shoulder in the cylinder, but are held securely in place by a nut adjustment on the exhaust bonnet and the valve and cage complete can be removed with the bonnet.

Steam and exhaust valves are operated by cams acting against rollers mounted on the outer ends of the valve stems, these cams being mounted on a hollow shaft which derives its motion from the crank shaft by means of spiral gears. Operation of the valves is automatically controlled by means of a rod which regulates the cam action according to position of the speed and pressure governor.

Recording pressure, vacuum and temperature gages are mounted on a large panel on the west wall of the engine room. Vacuum gages and most of the pressure gages were furnished by the American Schaeffer and Budenberg Corp., while the Bristol Co. supplied the recorders for feed water and flue gas temperature and also a recording pressure gage for the main steam line.

Exhaust steam from the uniflow engines and the air compressor is piped to a surface condenser, located in the basement of the engine room, having 1200 sq. ft. of cooling surface, and made by the C. H. Wheeler Mfg. Co. Two 14-in. oil separators, furnished by Crane Co., are installed in the exhaust lines just ahead of the condenser.

Exhaust Piping Provides for Engine Tests

One of the interesting features in connection with the condenser is the arrangement of the exhaust lines for engine tests. The two uniflow engines and the air compressor engine are connected to the condenser, cross connected into the heating system and also have a line for exhausting free to the atmosphere. This latter method is necessary when an air compressor engine is being tested in the shop. To accomplish this, a 6-in. live steam line and a 12-in. exhaust line lead from the power house through a tunnel, 10 ft. wide by 7 ft. high, to the shop erection department. After an air compressor is assembled, it is placed on the testing block, located above this tunnel. If it is provided with a steam engine, the 6-in. live steam line and the 12-in. exhaust line are connected to it, and the water rate of the engine determined, the exhaust being carried back through the tunnel to the Wheeler condenser and arrangements made to draw off the condensate into a tank erected on portable platform scales which may be moved into position for the test. During the period of the test, only the exhaust from the compressor engine on the testing block may enter the condenser and the steam from the main units in the power house is exhausted to the atmosphere or to the heating system, depending on weather conditions.

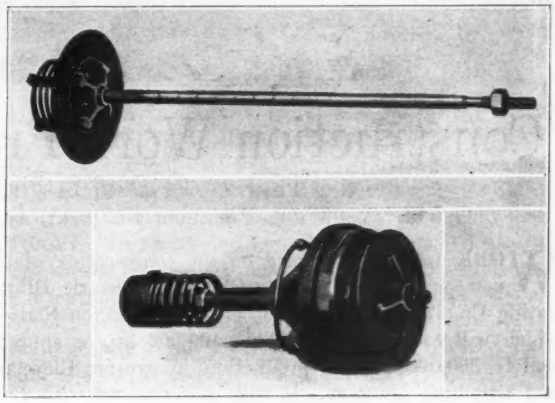
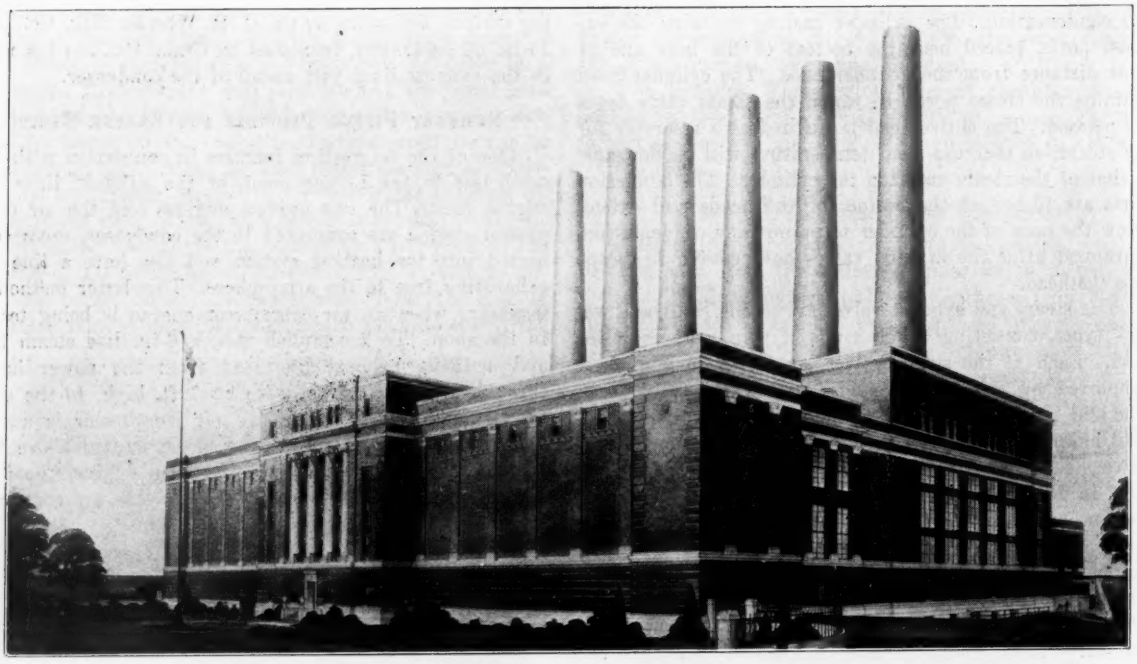


FIG. 5. UPPER—STEAM ADMISSION VALVE AND STEM. LOWER —STEAM EXHAUST VALVE, SEAT AND STEAM

Located in a tunnel directly beneath the center of the loading platform, a number of tanks for various kinds of oils are grouped together. Oils from these tanks are piped to all parts of the plant and are obtained at the point of use by S. F. Bowser & Co. hand-operated pumps.

Fire protection for the entire plant is given by the automatic sprinkling system and by a 6-in. fire pump, located in the basement of the engine room, which will handle 1000 gal. of water per min. against a pressure of 100 lb. per sq. in. This pump is a Dayton-Dowd Co. turbine driven centrifugal.

This plant, as well as most of the other structures for plants of the Sullivan Machinery Co., was designed by Arthur S. Coffin, architect and industrial engineer, Chicago, S. T. Nelson being the superintendent in charge of the plant and A. Eplett the power engineer.



Construction Work Progresses at Avon Station

NEW PLANT OF CLEVELAND ELECTRIC ILLUMINATING CO., DESIGNED FOR 300,000 KW. ULTIMATE CAPACITY, TO HAVE PULVERIZED-FUEL-FIRED BOILERS

WORK IS going forward on the construction of the new power plant of The Cleveland Electric Illuminating Co. at Avon Beach, to be known as Avon Station, which will eventually contribute 400,000 hp. or approximately 300,000 kw., to production in greater Cleveland and adjoining territory. It will be connected with Lake Shore Station by a "belt line of power" surrounding Cleveland, and, like Lake Shore Station, will tie in with the interconnected system which already extends over Ohio, western Pennsylvania, West Virginia and eastern Indiana. Simultaneously, an extension of the Avon Beach and Southern Railroad, which has become a C. E. I. Co. property, was projected into the station site and down to the lake front.

Avon Station and its auxiliary equipment will cover approximately 28 acres of land, including what formerly was Avon Beach Park, lying between Lake Road and the Lake Shore. The site is about 23 mi. west of the Public Square of Cleveland and 5 mi. west of Lorain. The plant proper will include, from north to south, a coal receiving house, a coal preparation house, a boiler room to house 12 boilers, a turbine room to accommodate six turbo-generators, a switchhouse and offices. The headpiece shows the architect's drawing of the station as it will ultimately appear.

FIG. 1. CONSTRUCTION OF SEA WALLS AND BREAKWATER AT AVON STATION

INITIAL INSTALLATION TO CONTAIN FOUR BOILERS AND TWO GENERATING UNITS

The 12 boilers to be installed at Avon will be similar to those in the east unit of Lake Shore Station and will be fired by pulverized coal. Steam will be superheated to 735 deg. by the boilers, which develop a steam pressure of 400 lb. per sq. in. Each boiler will normally be rated at 3060 hp. but will be capable of operation at three times that rating. The initial installation will consist of four boilers and two turbo-generators, each of which will develop approximately 35,000 kw. For the first four boilers two stacks will be built. Each stack will be 27 ft. in diameter at the bottom, 18 ft. 8 in. in diameter at the top and 175 ft. high above the station roof. Each pair of boilers in the station will be served by one stack.

The initial installation calls for a building which will be two-thirds of the ultimate size of the plant, as shown in Fig. 2. Some idea of the size of the ultimate structure is suggested by the fact that 11,000,000 lb. of steel will be required for its framework. The excavations for the building called for the removal of 58,000 cu. yd. of earth.

The turbine room will be equipped with a 125-t. traveling crane with a span 98 ft. long and tracks 315 ft. long.

An adequate supply of coal for Avon Station has been assured by the provision for storage facilities for more than 100,000 t. of coal and by railroad connections with the New York Central, Nickel Plate and Wheeling and Lake Erie lines, via the Illuminating Co.'s own railroad. The station will be equipped to pump water at the rate of 420,000 gal. a min. The intake tunnel will be 390 ft. long. The discharge tunnel for returning the water to the lake will extend the length of the turbine room floor, thence to the lake outlet. Its internal dimensions will be 15 ft. 3 in. high and 14 ft. wide. Figure 2 shows the station as it appeared only a few weeks ago.

Extensive Masonry Required for Basin and Breakwater

Another tunnel will be constructed to provide an outlet for the water from Avon creek, which now flows almost through the center of the Avon property. This tunnel will be 14 ft. wide and 11 ft. high inside. Extensive stonework will be required to surround the settling basin for the intake water and the basin for the outlet tunnel. The intake basin will be 600 ft. wide and 700 ft. long and will be dredged to an average depth of 15 ft. The masonry enclosing the basin will be constructed of sandstone with a limestone core. Seventy-six thousand tons of stone will be required. It is estimated that 60,500 cu. yd. of earth must be taken from the lake bottom to clear the basin.

East of the basin is to be the breakwater, 1350 ft. long, as shown in Fig. 1. For its construction 29,400 t. of stone will be required. The discharge tunnel will pass through the breakwater and dredging to the extent of 9000 cu. yd. will be necessary at its outlet. Part of the warm water from the discharge tunnel will be diverted to the mouth of the intake tunnel to keep the temperature at this point well above the freezing temperature.

Near the eastern end of the property will be located the substation for stepping up the power delivered by the plant from 11,000 v. to 132,000 v. for the high tension system.

FIG. 3. AIRPLANE VIEW OF AVON STATION TAKEN IN SEPT., 1925, SHOWS LOCATION ON LAKE FRONT

Avon Station is designed to replace the former plant of the Cleveland Electric Illuminating Co. that was located near the new site and that was destroyed by fire some time ago. Work on the new station has been going on since March, 1925, and progress has been extremely rapid and satisfactory. In the design of the station, many features of engineering interest are incorporated and, in addition, much attention has been given to the architectural details. The result, shown in the headpiece, will be an important addition not only to the power service of the Cleveland district but also to the architecture of the city.

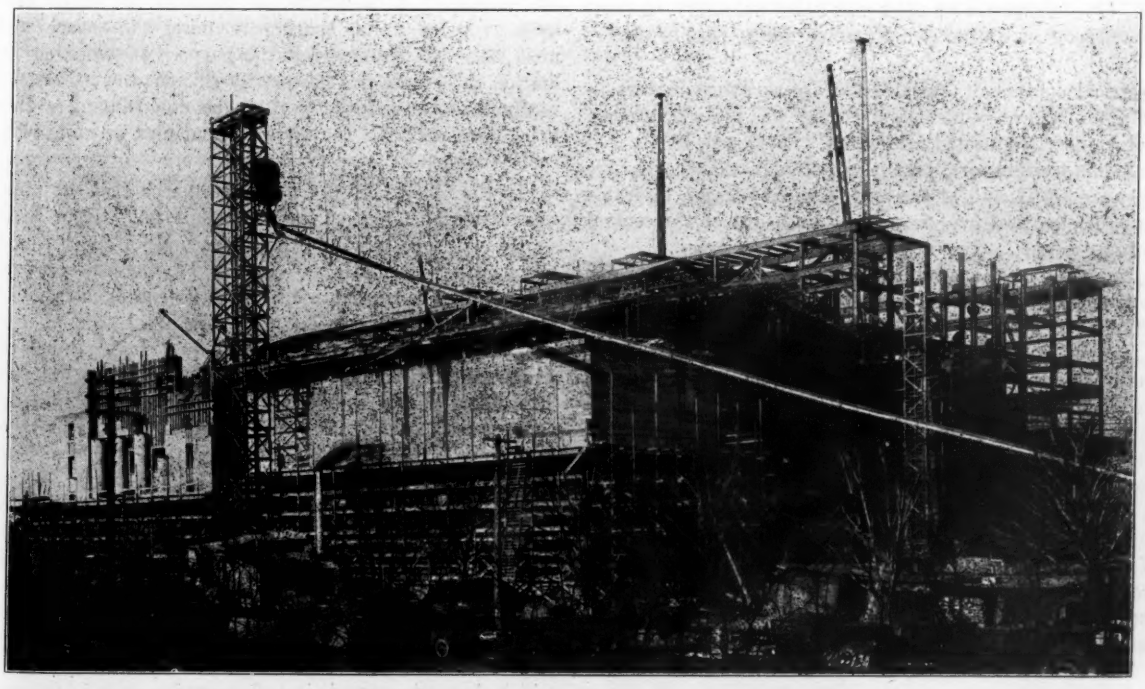


FIG. 2. AVON STATION AS IT APPEARED A FEW WEEKS AGO, SHOWING PROGRESS OF STEEL AND CONCRETE WORK

Remodeling Ice Plants to Fit Modern Conditions

By Taking Advantage of Raw Water Systems, New Types of Compressors and Drives and Latest Condenser Equipment, Remodeling Often Leads to Further Economies. By J. L. Gilson*

DURING THE PAST eight years, there has been a great deal of activity all over the country in the ice plant field, along the lines of plant remodeling. The need of such remodeling was brought about by the fact that the original distilled water type of ice plants had become obsolete and that a number of inventions and new ideas in plant engineering coming rapidly one after the other, brought about a condition in which it was absolutely necessary for practically every plant owner to modernize his plant in order to compete and stay in business.

The principal new developments were the perfection of several systems for making raw water ice, and along with these a number of revolutionary changes in the design of

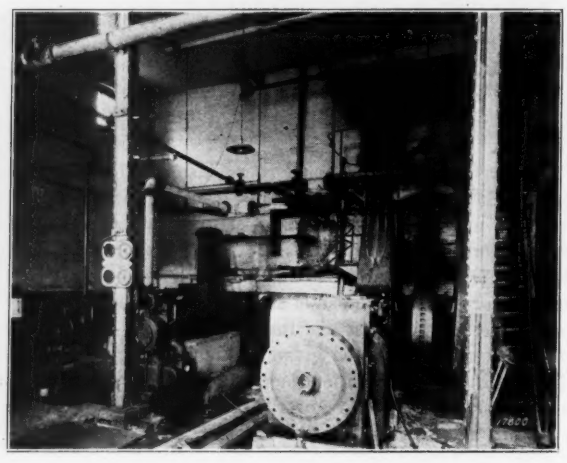


FIG. 1. COMPRESSOR AT LEFT HAS SAME CAPACITY AS COMPRESSOR AT RIGHT AND OCCUPIES MUCH LESS SPACE

electrical equipment, suitable for use as prime movers in ice plant layouts. Chief among these was the synchronous motor, direct connected to the newly developed, high speed ammonia compressors, permitting of high efficiency in the ice plant itself, and at the same time creating a desirable form of electrical load from the standpoint of the central station.

As soon as the advantages of raw water ice became apparent and the public began to demand ice of this kind rather than the older form of distilled water ice, which had a number of objectionable features, such as poor appearance, bad odors and flat taste, designing engineers began to see that modern methods and the new developments could be used, not only where plants were electrically driven, but also where cheap power was not available and where the use of steam engines would be required. In these plants it was then possible to apply highly economical types of engines, which heretofore had not been considered because of the need of a large quantity of distilled water made from the condensed steam from the engine exhaust, and the requirement was in such quantities that there was no need of high efficiency in this part of the plant.

In a number of cases, new plants have been built and old plants have been remodeled, using internal combustion engines, both gas and oil, as a means of driving the compressor units. There has been only a limited amount of success along this line, however, on account of the noise, vibration and other features of oil engines themselves, and the fact that breakdowns seem to be more frequent in these plants than in the steam and electrically driven ones. While efficiency is of the utmost importance in ice plants, it does, however, rank below the question of reliability from the viewpoint of the ice plant operator. His load factor is a very poor one. He must produce quickly and surely during that part of the year when his business is at its peak, and a breakdown during this period would cause him greater losses than he could ever make up by the use of machinery that, while efficient, might lack something in the way of reliability.

This article, therefore, will treat principally the electrically driven and steam driven plants, emphasizing the electric, which comprises approximately 80 per cent of all the plant remodeling which has been done.

Utilizing the Existing Plant As a Basis

When a plant has reached a point where it is apparent that changes and remodeling will be necessary, one of the first things to be considered is to determine definitely just what part of the present plant is still in good condition and of such design as to make it not entirely obsolete or unusable and what parts can, either in their present state or with some slight changes, be advantageously used in the new plant layout. A careful analysis should be made of the question of what material might be sold as second-hand and what material must be junked. Then again, there is the possibility of a number of parts of the plant being used as spare units, bearing in mind that spare units must, after all, simply serve the purpose of temporary operation and, while not necessarily efficient themselves, will nicely take care of the work to be done during a short breakdown period of the more efficient unit or units which replace them.

In the older type of plants, the mechanical equipment was carefully arranged and the building purposely designed with the old distilled water cycle of operation in mind. The requirements of modern practice are somewhat different and in a great many cases a re-arrangement of the plant layout itself can be effected, making a more compact and closely assembled unit, thus reducing labor cost and permitting closer observation by the operating crew. The older type of engine rooms and boiler rooms had to be of great head room. With modern equipment, these rooms might be advantageously used for entirely different purposes and some other space of low head room and possibly of more convenient location, used to house the ammonia compressors. In a great many cases, the older engine and boiler rooms have been handily converted into ice storage space, and in some instances, new floors have been built, making separate rooms of the upper part of the old engine rooms and creating, with little expense, some desirable extra space. This is well illustrated by Fig. 1, which shows the remodeling of an engine room in progress. One only has to look at this construction picture to see

*Associate of Van Rensselaer H. Greene, Consulting Engineer, New York.

what can be accomplished along the lines of space saving, at the same time reducing the operating problems. The two machines shown in this picture are of the same refrigerating capacity and are a good illustration of the great strides that have been made in ammonia compression machinery development.

Not only does the use of modern equipment open up the possibility of using the extra head room, but it also provides, in a great many cases, an engine room occupying much less floor space. Figure 2 shows a new set of modern compressors occupying almost half of the floor space formerly occupied by an older type of machine of slightly less capacity. The outline of the older unit can be plainly seen in the floor, which had not been refinished when this picture was taken.

In some instances, where the continuous operation of the plant cannot be interrupted for a sufficient length of time to remodel the major part of the equipment, it has been found desirable to select another room or build a new room to house the new equipment. Figure 3A illustrates an instance of this kind, where a part of what was formerly a covered driveway was enclosed and made into a neat and clean-cut modern engine room.

Considering the Electrically Driven Ammonia Compressor

Let us now consider in detail each one of those parts usually concerned in remodeling work, the first of which will be the ammonia compressors. In general, wherever central station power can be purchased for 1¾c per kw.-hr. or less, it will always be well to favor electrically driven compressors, except in cases where an unusually low price for coal prevails.

Wherever the old compression equipment must be removed and new machines installed, and where the machines are of larger capacity than 50 t. of refrigeration per day, the use of synchronous motors, direct connected to the compressor shafts, is always desirable. This type of drive does away with the objectionable features of belts or chains. Almost every plant installing new electrical machinery has installed this type of drive, so that it might well be said that this is a new standard for new compressors. A number of the pictures shown here illustrate machines of this type. Note particularly, however, Fig. 3C, illustrating a job where synchronous motors were direct connected to the shafts of machines which had formerly been driven by rope drive from gas engines. The driving wheel for the rope drive was removed and the synchronous motor installed in this space. In this particular instance, there was only sufficient room for the new motor itself without any space provided on the shaft for flywheel effect. The motor manufacturers, however, easily overcame this difficulty by obtaining the necessary flywheel effect in the rotor of the motor itself. This particular case illustrates the flexibility of application of this type of drive and the special modifications which are easily obtained. Drives similar to this can be installed anywhere where the present compression machinery is in good condition and of such a type as to permit of what might be called medium speed operation.

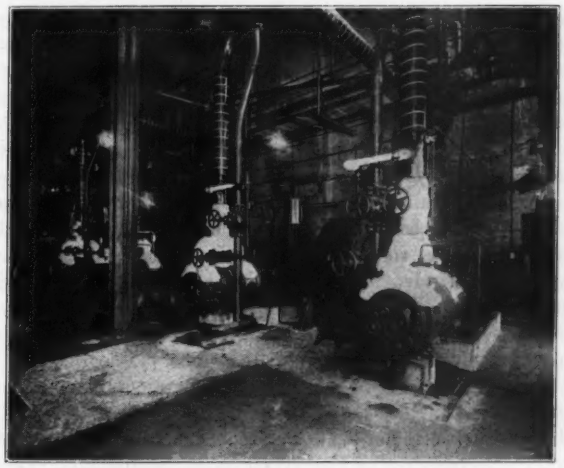


FIG. 2. OUTLINE ON FLOOR SHOWS SPACE OCCUPIED BY OLD COMPRESSOR, WHICH HAD LESS CAPACITY THAN THE TWO MACHINES NOW MOUNTED ON ONE END OF THE FOUNDATION

In a great many instances, compressors can be speeded up without any changes to machines themselves, and in other cases by the simple method of exchanging the old

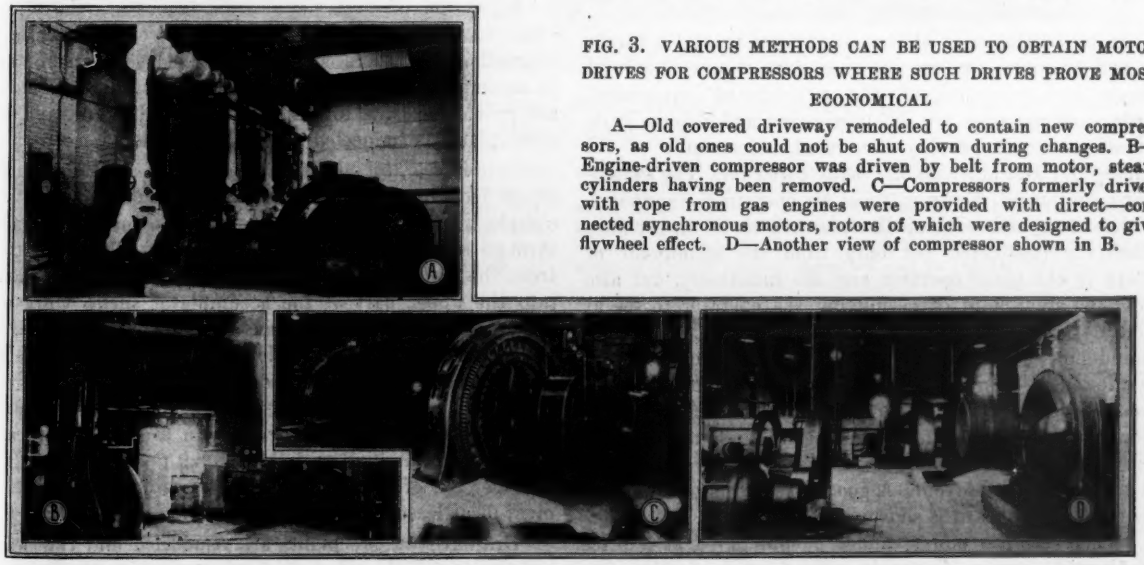


FIG. 3. VARIOUS METHODS CAN BE USED TO OBTAIN MOTOR DRIVES FOR COMPRESSORS WHERE SUCH DRIVES PROVE MOST ECONOMICAL

A—Old covered driveway remodeled to contain new compressors, as old ones could not be shut down during changes. B—Engine-driven compressor was driven by belt from motor, steam cylinders having been removed. C—Compressors formerly driven with rope from gas engines were provided with direct-connected synchronous motors, rotors of which were designed to give flywheel effect. D—Another view of compressor shown in B.

type of poppet valves for new plate type valves made to fit into the old valve housings. Some of the older ice machine manufacturers are providing these new types of valves themselves and there are one or two manufacturers who have specialized in this work solely.

In some plants, while the compressors themselves might be in exceedingly good condition, it is not possible in the allowable space to install a synchronous motor, and in such cases the belt drive must be used. There is almost always sufficient room to provide a belt wheel in the space formerly occupied by the flywheel and the valve gear mechanism. Figures 3B and 3D illustrate a remodeling job of this kind where a belt drive was used and a high speed synchronous motor installed. The plant illustrated was formerly a steam driven plant operated by a simple steam engine. The steam engine cylinders were removed, the wall between the old boiler room and the engine room was torn down, and the synchronous motor and other

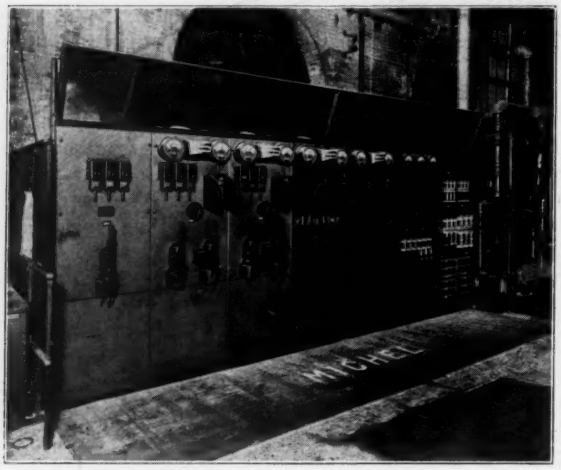


FIG. 4. NEW SWITCHBOARDS SHOULD BE DESIGNED FOR CONVENIENCE, SAFETY AND GOOD APPEARANCE

auxiliary equipment were located where the boilers formerly stood.

Selection of Switchboard is Important

In connection with electrically driven plants, it might be well to point out here the great importance of careful design and selection of the switchboard equipment. Modern compressors are self-lubricating and require little attention, except possibly occasional adjustments of the stuffing box and other details easily cared for. The switchboard equipment, however, from an operating standpoint, is the heart and soul of the plant, and its importance should be considered not only from the standpoint of safety to the plant operator and the machinery, but also from the standpoint of permitting the operator to see at all times just what his plant is doing. Necessary meters should not be omitted and sufficient space should always be allowed so as not to create a crowded or unsafe condition. There is, perhaps, no part of a remodeled engine room which will go as far, from the standpoint of appearance and the development of pride in the operating crew, as the switchboard layout. A good illustration of a modern ice plant switchboard is shown in Fig. 4.

Where electric power cannot be purchased at a price which will compare favorably with the use of steam engines, and in general where the cost of current is 2c per kw.-hr. or more, we enter upon the field where highly economical steam engines are desirable. For ice plant work, both the uniflow engine and the compound poppet valve engine, either of which can be operated advantageously with vacuum and superheat, are usually considered because of their efficiency and the possibility of connecting them directly to the ammonia compressors. Steam turbines, while possibly more efficient in the larger sizes, have seldom been used because of the problem of a suitable drive to the compression machinery.

Not only in the engine room but in the boiler room of such remodeled plants do we find an opportunity to make alterations which will greatly benefit the plant from an economy standpoint. Where the old boilers are still in good condition, it is almost always advisable to raise the boilers and provide high settings, in accordance with modern practice. This change is of such importance that even in cases where the head room in the boiler room does not permit of raising the boiler shells themselves, the boiler room floor has been lowered, thereby creating the equivalent of a higher setting. In one such alteration, the floor level was lowered at the front of the boilers and a steel plate about 15 in. wide was used to fill the gap in the old boiler front.

Changes Should Often Be Made in Ice Tank Room

Next in importance to the engine and boiler room is the ice tank room. All of the older plants had a limited bulkhead space at the end of the tank where the brine was led to the agitator propellers. Modern practice calls for a bulkhead at least 18 in. wide, and where this additional width cannot be obtained by moving partitions within the tank, it has been considered advisable to go to the trouble of building an extra bulkhead sluice-way out on the end of the tank, being careful in such an operation to see that the vibration of riveting a new part to the tank does not loosen the joints in the rest of the tank at the bulkhead end.

Another important change in ice plant layout, which should always be made wherever possible, is the conversion of the old ice tank coils, which are usually arranged on the direct expansion system, to a modern type of gravity feed flooded system. Where the original layout has the piping arranged in horizontal zigzag coils, this change is almost impossible, but where coils are arranged vertically, it can be accomplished without a great deal of trouble. Headers are provided at the top and bottom of the tank and the accumulator is connected up to these headers.

Note in Fig. 5E, illustrating a flooded system, that the liquid feed line drops to the bottom header level on the outside of the tank and then connects into the header through stuffing boxes in the tank shell. The gas return from the coils to the accumulator is connected as shown into the upper part of the accumulator shell. Only one expansion valve is used on an arrangement of this kind, the liquid being fed into the lower part of the accumulator. The installation of a system of this kind not only permits of greater ease of operation, but also makes much better use of the pipe surface provided. In a great many cases a system of this kind will operate with 200 ft. of 1¼ in. pipe per ton of ice making capacity, as against a requirement of at least 300 ft. for a direct expansion system.

Ordinarily where plants are remodeled and raw water systems installed, it is necessary to provide complete new

framework and covers, although in some cases it has been possible to use the old framework by making alterations or additions to it. While there is possibly some advantage in the way of a saving in first cost in making additions to old framework, it is doubtful whether this is real economy. Such altered framework usually lasts only a year or two and then new material has to be provided. It probably would be well always to consider new framework and to leave as a question only whether or not new covers should be provided.

In modern plants, of course, new covers are made to fit over two or three or even more cans, thereby saving time for the can puller and keeping the tank top in a much cleaner condition. Figure 5A shows a plant where new framework was installed, but where the old covers were again used. Alongside the columns in the center of the room can be seen the air agitation system with the air laterals leading below the can covers. Figure 5D shows a plant with complete new framework and covers, each cover arranged to take care of two cans.

In modern plants, an important development, looking to the saving of labor, has been the introduction of multiple can harvesting. In the new plants, the tanks are usually arranged so as to permit of basketing the cans, which is undoubtedly preferable when a number of cans are to be handled at once. Usually, however, when plants are remodeled on account of the coil spacing and tank design, it is not possible to do this. The advantages of multiple can harvesting, however, can be obtained by the use of a specially designed crane and can lifting arrangement, as shown in Fig. 5C. A crane, having a crossbar reaching over six cans, was installed and in order to prevent the cans from swinging, special can dogs were provided, each dog having two chains. In some plants, in addition to these devices, there have been installed squaring devices which are lowered onto the top of the cans when they are pulled from the tank and hold them rigidly in place while they are taken to the can dumping and refilling equipment.

Figure 5C also illustrates another interesting situation, in that it is a can tank system installed in a space formerly occupied by the old and obsolete plate system. The old

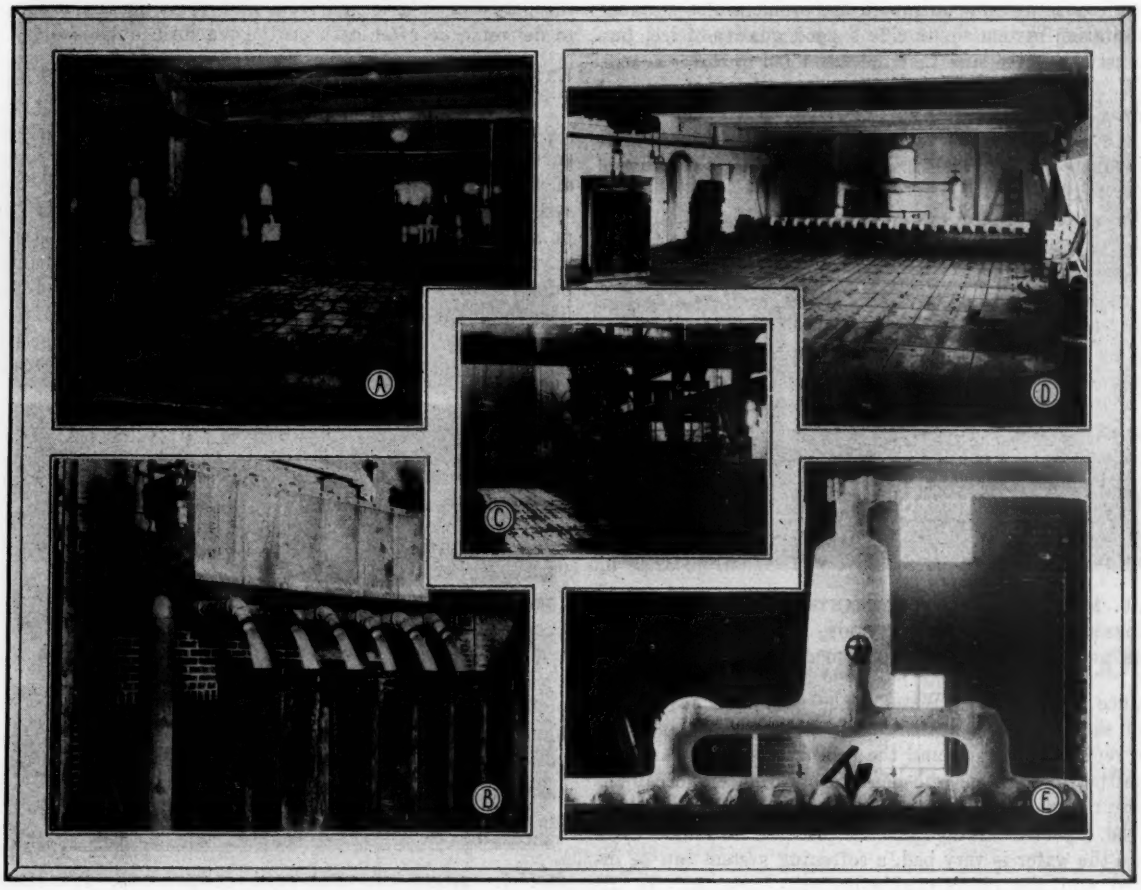


FIG. 5. ICE TANK ROOM OFFERS GOOD FIELD FOR REMODELING OPERATIONS, TAKING ADVANTAGE OF THE MOST RECENT DEVELOPMENTS AND EQUIPMENT

A—New framework was installed here, but old can covers were kept. Note air agitation system at side, with laterals to cans. B—Modern method is to fill cans at dump, as shown here, instead of with can fillers. C—Multiple can harvesting finds favor, as it reduces amount of labor needed. This can system was installed in space formerly occupied by plate system, using old tank shell and providing new coils, frame and covers. D—Use of covers to fit two or three cans, as shown in this remodelled tank, often saves time for can puller and keeps tank top cleaner. E—With vertical coils, liquid feed line can be connected between accumulator and headers as shown here. Such an arrangement leads to greater ease of operation and to higher economy.

tank shell, which formerly served for the plate system, was used in the new layout and new coils, framework and covers installed.

Hand in hand with the coming of the multiple harvesting system has come the almost standard system of filling the ice cans at the can dumps, rather than with the old type of can fillers, which were moved about the tank top. Figure 5B illustrates a system of this kind installed in a remodeled plant, the can dumping equipment being specially designed to correspond with the crane and harvesting arrangement illustrated in Fig. 5C.

When a plant is converted from steam to electric drive, we are confronted not only with the problem of a suitable air agitation system to provide a good quality of ice, but we must also make sure that the water fed to the cans will

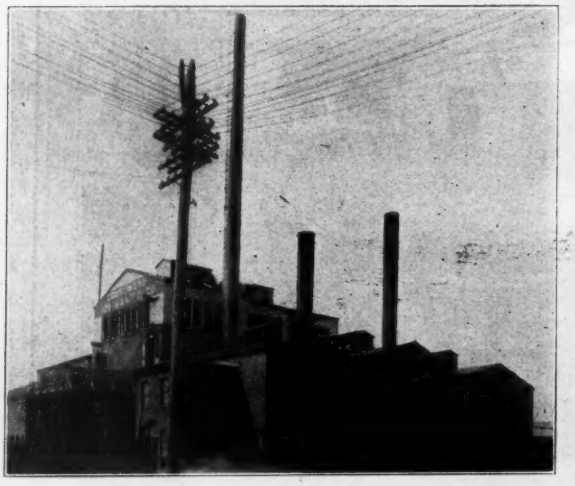


FIG. 6. MANY OLDER TYPES OF PLANTS INSTALLED AMMONIA CONDENSING EQUIPMENT ON ROOF, WHERE IT OCCUPIED MUCH SPACE AND REQUIRED CONSIDERABLE PUMPING POWER

produce a clear cake. Water to be used in a raw water plant should always be thoroughly and carefully analyzed by a reputable chemist and the results of such an analysis submitted to someone who has had experience and can interpret the meaning of such an analysis as relating to what can be expected in the finished product. In some cases where the water is very bad, a softening system can be installed and the objectionable contents removed. In almost every instance, a sand filter of large size with a slow rate of water flow can be advantageously used.

Storage Room Insulation and Conveying Devices

Another important problem which always comes up for solution when a plant is remodeled is the question of suitable insulation for the ice storage rooms, which are usually enlarged or augmented at such a time. In the past, insulation has been applied usually in a bed of Portland cement mortar, with no consideration given to the waterproofing of the insulating material between itself and the wall upon which it is applied. A great deal of research work has recently been completed, proving conclusively that something in the way of a thorough waterproofing is required at this point. Insulating contractors will usually hesitate to recommend this method of application in the face of competition. Nevertheless the plant owner might well insist upon a specification which will include this important feature.

Further consideration in connection with storage ro is the possible use of conveying and benching machine A great many benching devices are now on the mark both hand and electrically driven and these have prov to be of great benefit in the handling and storing of ic More recently we have seen the development of conveyors of the chain type installed right in the tank room floor, in such a way as to give the very minimum of labor by the storage room men. In a plant which has just been completed, a chain conveyor runs the entire length of th storage room and the platform men can go into the room completely load this chain with ice and then proceed t the platform outside and from that point operate it so as to deliver cake after cake on the platform outside.

Extreme Care Needed in Remodeling Ammonia Condensing System

We now come to what is probably the most important part of any plant when considered from a remodeling point of view. This is the question of the ammonia condensing system. In all of the old plants, where it was necessary to pump water first over the ammonia condensers and then have this same water flow by gravity and without further pumping over other cooling coils, heat exchangers and the like, the plant was always arranged with condensers of the pipe coil type on the roof of the building or in a special structure built high up above the rest of the plant. While

FIG. 7. SHELL-AND-TUBE-TYPE CONDENSERS, INSTALLED WITH SPRAY POND SHOWN IN FIG. 8, OFTEN SAVE MUCH ROOM AND REQUIRE LESS PIPING AND LOWER PUMPING HORSEPOWER

this represented economy in the old distilled water plant, in plants of the new type where raw water systems are used, there is no need of the condensers being so located and if space can be provided at lower levels with lower pumping heads, such a change is of the utmost importance.

In former days, before cooling towers and spray ponds had been perfected, ice plant owners went to great expense to drive wells or to procure cold water from other sources. While in a great many cases this proved satisfactory and while cold well water, when certain as to quality and of unfailing supply, can well be used, even in new plants, we must not overlook the fact that extremely good results can now be obtained with cooling towers or spray ponds and that, when these are used, there is absolutely no danger of a lack of water at the time when it is most needed.

Figure 6 shows a plant of the older type. The wooden structure on the top of the building houses the ammonia condensers, and other condensing apparatus has been installed on an elevated platform along side of the building. In this particular instance, the plant was located on the river front and water was pumped from the river up and over the pipe stands. Compare this now with the thoroughly modern condensing system illustrated in Figs. 7 and 8.

FIG. 8. THIS SPRAY POND, USED WITH SHELL-AND-TUBE-TYPE CONDENSERS SHOWN IN FIG. 7, WAS INSTALLED ON ENGINE ROOM ROOF

Figure 7 shows a system using two horizontal shell-and-tube type ammonia condensers. Below and in between is located the ammonia liquid receiver and, under one end are the motor-driven centrifugal pumps, pumping the cooling water through the condensers and through the spray pond cooling system. The spray pond, illustrated in Fig. 8, is located on the roof of the building immediately above the engine room, in which the condensers are located. One can readily see that this means a minimum of pumping horsepower and a small amount of circulating water piping. The system illustrated has a capacity in daily ice production equivalent to that of the plant shown in Fig. 6. A comparison of these two plants, therefore, shows what can be accomplished by the use of modern equipment in the way of compactness, accessibility and efficiency. In spite of the fact that the plant illustrated in Figs. 7 and 8 is located in a city in the southern part of the country, during midsummer weather this plant was operated with a condenser pressure not exceeding 165 lb. While it is usually considered better practice to install horizontal shell-and-tube condensers where a spray pond is used and a large volume of water circulated, shell-and-tube condensers of the vertical type might also well be considered where the quantity of water is not so great but the temperature lower.

The purpose of this article has been to cover as well as possible all of the more important questions entering into the problem of plant remodeling. Undoubtedly, there are a great many smaller details which can well be considered in each individual plant, wherein the ingenuity of the chief engineer and the plant manager can be called into play, to produce a plant which will not only be modern from an engineering standpoint, but which will also be clean, sanitary and of good appearance, so that the plant's customers can at any time be invited to inspect such a plant. This, of course, could not very well be done in some of the plants of the older and more complicated type.

Feeding of Warm Liquid Ammonia Causes Loss

COMPUTATION OF AMOUNT OF THIS LOSS, TOGETHER WITH DISCUSSION OF COOLING TOWER AND ABSORPTION PLANT OPERATION, ADD INTEREST TO N. A. P. R. E. MEETING. BY CHARLES H. HERTER

HEREWITH are given the principal points of some helpful discussions at the first meeting of its second year, held in January by New York Chapter No. 2, N. A. P. R. E.:

DETROIT CONVENTION REPORT

J. Bernd, delegate to the Detroit N. A. P. R. E. convention, told of his impressions of that great gathering. He dwelt on the findings of the Corrosion Committee, told what was said on preventing cracked ice, on cooling towers and spray systems. Mr. Bernd was particularly impressed with the comparison some convention engineer had made between the evaporating of ammonia and water. The man had stated that it was equally uneconomical to feed warm liquid into a refrigerating system as it was to send cold water into a steam boiler. Also, that this loss amounted to 17 per cent of the refrigerating power of the liquid, which loss should be reduced. Mr. Bernd suggested that this conclusion be verified. He further said, that 412,000 B.t.u. ÷ 288,000 = 1.43 t. refrigeration had been declared sufficient for making a ton of ice from water at 60 deg., and that theoretically, at least, it was wasteful to forecool the can water with suction gas colder than 30 deg. F.

To check the figures on that 17 per cent loss, the writer made the following calculation, the values for properties of ammonia being those published by the Bureau of Standards:

LOSS IN FEEDING WARM LIQUID AMMONIA

Utilizing data given Dec. 1925 in an A. S. R. E. paper by L. H. Jenks, we note that in Test 17, for example, the conditions were as follows:

Temperature of water to condenser	66.64	deg. F.
Temperature of water from condenser	79.22	deg. F.
Condenser gage pressure	155	lb.
Saturation temperature corresponding to condenser pressure	86	deg. F.
Temperature of liquid before expansion valve	80	deg. F.
Suction pressure, gage	19.6	lb.
Corresponding ammonia temperature	5	deg. F.
Ammonia temperature at outlet from cooler	15	deg. F.
Liquid circulated per minute	34.6	lb.
Refrigeration accounted for by brine	84.2	t.
Refrigeration due to weighed liquid ammonia	84.7	t.

To verify these figures, we note that the latent heat of

evaporation L of ammonia at 19.6 lb. and 5 deg. = 565 B.t.u. per lb.

This gross amount of cooling is not obtained, because the warm liquid must first be cooled by itself from 80 deg. down to 5 deg. In this interval the specific heat of liquid ammonia averages 1.116, hence $1.116 \times (80 - 5) = 83.7$ B.t.u. are lost, the net useful effect being 565 — 83.7 or 481.3 B.t.u., which is but 85.2 per cent of 565 B.t.u. At 200 lb. cond. pressure, with 100 deg. liquid, the result would be 565 B.t.u., less the difference in heat content of liquid at 100, and at 5 deg. this difference is 155.2 — 48.3 or 106.9, which leaves a net of 458.1 B.t.u. per lb., so that in this less favorable case we have 81 per cent of 565, or a loss of 19 per cent.

The 481.3 B.t.u. suffices for $481.3 \div 200 = 2.4065$ t. refrigeration, and as 34.6 lb. were circulated per minute, the cooling effect of this ammonia amounts to $34.6 \times 2.4065 = 83.25$ t. This may be increased by charging up the 10 deg. of superheating of the suction gas, which added 4.6 B.t.u. per lb. times $34.6 = 159.2$ B.t.u. or 0.8 t., making the total work 84.05 t.; this figure agrees practically with the values given in the paper. Should any liquid return unevaporated with the suction gas, or liquid be injected just for cooling the cylinder, the net useful refrigeration is correspondingly diminished.

The 15 to 19 per cent loss can be reduced only if the condenser pressure is lowered, or if cold well water or ice water is available for subcooling the liquid. Suppose its temperature could be depressed by water or scrap ice to 36 deg. F., then we would lose only $565 - (82.3 - 48.3) = 531$ B.t.u., which is 94 per cent of 565, or but 6 per cent loss. Whenever the conditions permit, it is proper to subcool the liquid without employing ammonia for this purpose.

Life of Cooling Towers

Mr. Schildwachter wanted to know the probable length of useful life of a water cooling tower. The reply was that this depended upon the materials of construction, on the local gas contamination, on the character of the water used (no thawing tank water should ever be mixed with the cooling water) on the care taken to prevent ice formation in freezing weather, and on the thoroughness of annual cleaning and quality of paint applied. A useful paint for this and other severe situations up to 600 deg. F. seems to be Quigley Triple-A Solution; this is acid, alkali and water-proof, for metal, wood and concrete.

The structural skeleton usually contains no steel thicker than ¼ in. If painted every year, this may be expected to last 25 to 30 yr. The Dupont Everdur Co. is offering Everdur, a noncorrosive metal, in all conceivable shapes, which seems well adapted for use in cooling towers. Noncorrosive steels are also being sold by Crucible Steel Co. of America. The galvanized spray preventer sheets must be replaced every four to five years, hence the modern practice is to use corrugated sheets of zinc, at least 0.028 in. thick, anchored with ⅜-in. galv. stove bolts and washers. These sheets are expected to last 25 yr.

Cypress wood trays constituting the decks for breaking up the falling water would last forever if the weight of ice in the winter did not break them down, so that 10 to 20 per cent of them must be replaced every spring. The catch pan of 1¾-in. planks lasts as long as the tower, especially if treated with a hot solution of Carbolenium Avenarius wood preserver.

Flow of Weak Aqua Ammonia

The following problem was next discussed by Mr. Collins and Mr. Anderson: In an absorber of the double pipe type, should the weak liquor flow downward or upward for best efficiency?

As Mr. Anderson has acquired experience with both methods, he was able to explain that downward flow was most satisfactory for the same reasons that in condensers the ammonia now flows downward. He sketched a layout on the blackboard, and said that the weak liquor of, say 22.5 per cent NH_3 content was hungry for the gas supplied by the brine cooler, to become enriched to, say 34.3 per cent. This causes foam, and if the aqua in a 10-pipe high absorber flows upward, the action is not steady. Unless the strong liquor receiver is then extra large, the pump will not function properly. It will pump gas instead of liquor, and will slow down, interrupting the supply of strong liquor to the generator, where more vapor will be boiled off. The improved method is in successful use at the Mt. Sinai Hospital, New York. The heat of absorption is removed by cooling water flowing counter-current to the liquor. In atmospheric absorbers, having water showered over the outside, the flow of liquor is upward for the sake of securing counter current.

Cell Concrete Insulation

From an article in a German magazine, the writer translated an item stating that Christiani and Neilson, Danish engineers, Copenhagen, have secured a patent on a new fire resistive building material which is said to have necessary strength and heat insulating quality. It looks as if made of fine pumice. It is named "cell concrete," is hard like concrete, yet floats in water, its specific gravity for insulation, being 0.25 to 0.90. The denser the mass, the greater is its strength, of course. Cell concrete can be made right on the job by mixing in an ordinary concrete mixer sand and cement. Into this mixture is blown through a pipe a foamy liquid beaten up in a separate beater. The more of this frothy material is added, the lighter will be the resulting concrete.

The pores or cells are said to be closed and watertight and therefore not hygroscopic. There is no information given as to actual heat conduction, but a cell-concrete wall 12 in. thick weighing 50 lb. per cu. ft. (spec. grav. 0.8) is likely to conduct no more heat than a brick wall 24 in. thick, or corkboard 2 in. thick.

Neuhof Installs World's Largest Diesel

In the power plant Neuhof near Hamburg is being installed the world's largest Diesel engine. According to the VDI-Nachrichten of Jan. 20, 1926, it is of the two-cycle, double-acting type with the M.A.N. slit flush system. Shop tests conducted by its builders, Blohm & Voss, licensees of M.A.N. indicated for the nine cylinders an output of 14,790 brake horsepower at 94 r.p.m. The stroke is 59 in. and the cylinder diameter 34.9 in. The gigantic proportions of this Diesel are shown by the following figures. Its length to the coupling flange is 76.8 ft.; its greatest width is 14.1 ft.; its height from the shaft center to the top of the valves of the cylinder covers is 32.8 ft., and 38.7 ft. when measured from the lower edge of the oil basin.

Threats of physical chastisement do not change the basic facts.

Superheaters Are Needed in Small Plants

As SUPERHEATERS are so generally used in large power plants and on locomotives it is natural to ask why the advantages of superheated steam cannot be secured in small industrial plants.

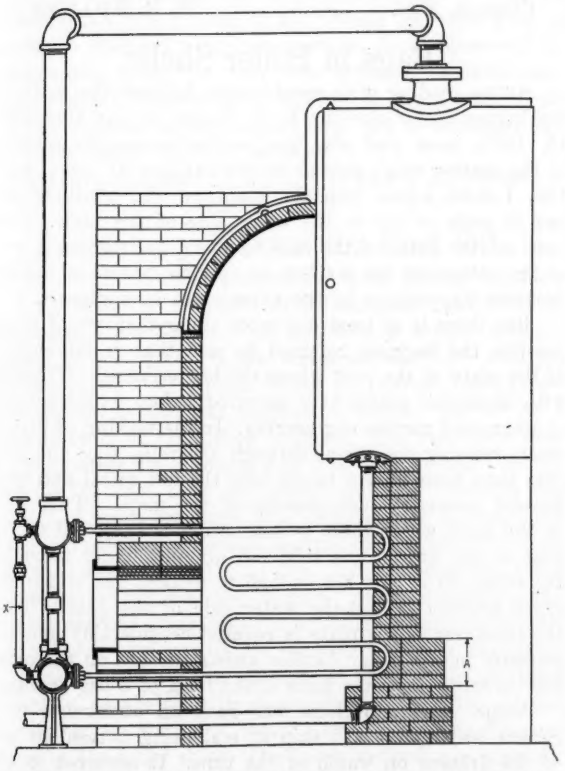


FIG. 1. THIS IS AN EXCELLENT METHOD OF INSTALLING A SUPERHEATER FOR AN H. R. T. BOILER, AT THE REAR OF THE FURNACE

Undoubtedly there is a wide field here for superheated steam but proper conditions must be observed to secure the full advantage. For instance, in many existing plants the steam piping system must be overhauled to take care of the greater degree of expansion in the pipes due to the high temperature of superheated steam; otherwise there will be fractured fittings or new leaky joints. In new installations, however, proper provisions can be made to take care of this.

There are some conditions where high temperature is a disadvantage; for instance, Corliss engines cannot be used where the temperature of the superheated steam exceeds 450 to 475 deg. F. In cases where a nearly constant temperature is needed, it will be found that close control of superheat is difficult.

A simple and relatively inexpensive superheater as applied to a horizontal return tubular boiler is illustrated by Figs. 1, 2 and 3. Such an installation has been in operation for over 3 yr. without any failure or fatigue. The boiler, 72 in. diameter by 18 ft. long, is operated at 125 lb. working pressure and the temperature of superheated steam varies in operation from 475 deg. to 550 deg.

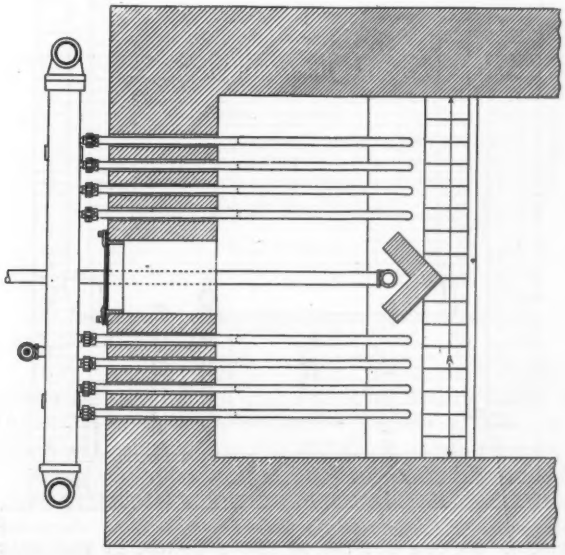


FIG. 2. HERE IS A PLAN VIEW OF THE SUPERHEATER

When the boiler is operated at a heavy overload the superheat occasionally goes to 600 deg. In this instance the fluctuation is not a serious feature and in most cases fluctuations to this amount will be of no disadvantage.

The accompanying figures will explain the general arrangement. A feature to be noted is the accessibility of the rear tube sheet of the boiler; also the ease of cleaning out at the rear. The usual back space between the back boiler head and the rear wall is normal and does not have to be increased.

In applying to old boilers it may be necessary to tear out a part of the rear wall to install the superheater coils, but after they are in place they can be removed and replaced without affecting this wall. The coils are free to expand without restriction and the arrangement of upper and lower headers permits a thorough drainage of the system. The drain should be open when firing up the boiler.

To modify the temperature of the superheated steam, a transverse horizontal wall marked A is used which can be

made higher or lower to give more or less superheat. The pipe marked X connecting the upper and lower headers, when open, will short-circuit a part of the steam and the temperature of superheat can be slightly modified.

When steam from a boiler is superheated it does not increase the amount of steam evaporated per pound of coal, neither does it increase the pressure of the steam; but, by this process, more heat is put into the steam and gives it more "pep." It lessens condensation in the entire system, particularly in pipes, pumps and engines. It also reduces leakage losses, as a superheated steam leak does not pass so much steam by weight as when using saturated steam. As a rule, the saving obtained varies from 10 to 15 per

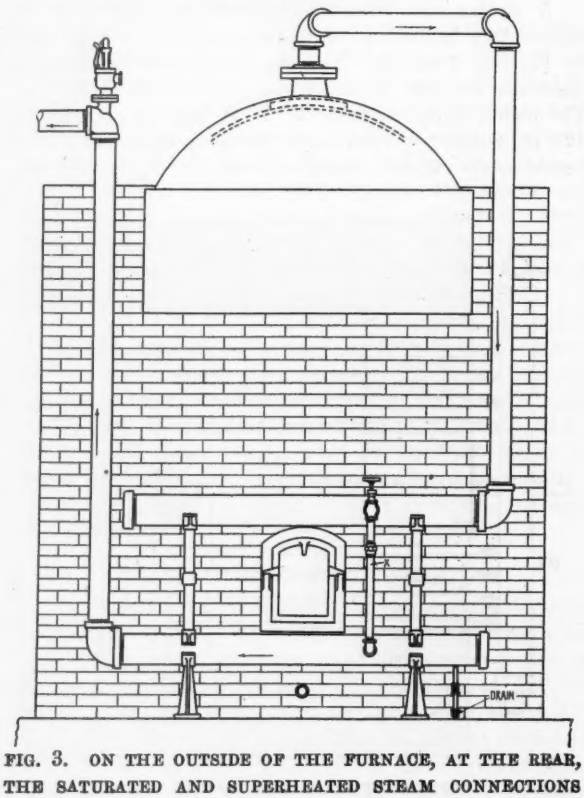


FIG. 3. ON THE OUTSIDE OF THE FURNACE, AT THE REAR, THE SATURATED AND SUPERHEATED STEAM CONNECTIONS LOOK LIKE THIS. NOTE THE BYPASS LINE (X); ALSO THE FURNACE CLEAN-OUT DOOR

cent, averaging about 1 per cent for each 10 deg. of superheat. In some cases a greater percentage can be secured where the condensation and leakage losses have been heavy.

The reduction of initial condensation in the cylinder of a reciprocating engine enables such an engine to be operated at earlier cutoff with a higher degree of expansion, which of itself gives improved economy.

When the demand for steam is heavy the superheat increases and the capacity of the boiler is increased because less steam is required per horsepower than when saturated steam is used. A superheater, therefore, helps in carrying peak loads.

Cincinnati, O. J. B. STANWOOD.

Steam Plant or Diesel Engines?

IN THE Feb. 1 issue, p. 224, there is an article by Einar Winholt entitled "Steam Plant or Diesel Engines" in which one or two statements are open to question.

First, let us consider the thermal efficiency of the plant. If we assume dry saturated steam at 155 lb. pressure, this steam would contain 1196.5 B.t.u. per pound. To generate one pound of this steam with a boiler efficiency of 70 per cent would require 1709 B.t.u. input to the boilers. If 18 lb. of this steam are used to generate 1 kw. hr., the input to the boilers would be 18×1709, or 30,762 B.t.u. If 1 kw-hr. equals 3412 B.t.u. and if per cent efficiency equals $\frac{\text{output}}{\text{input}} \times 100$, the thermal efficiency of the plant in question would equal $\frac{3412}{30{,}762} \times 100$, or a trifle over 11 per cent instead of 13 per cent as stated in the article. Neither would it be possible to have an overall efficiency of 70 per cent if the boiler efficiency alone were only 70 per cent, even though the exhaust steam should be used for heating.

Chanute, Kan. H. R. WILLIAMS.

Bags in Boiler Shells

AFTER reading with considerable interest the story of the bagged boiler shell by F. E. Hussey in the December 15, 1925, issue and also the various comments relative to the matter which appear in the January 15 issue, page 163, I must agree with the majority who attribute the bag to scale or oil on the water side of the plate. Perhaps all the facts in the case have not been brought out, so the comments are matters of opinion, based on similar previous happenings in the experiences of engineers.

But there is at least one more thing that would make possible the bagging referred to and that is lamination of the plate at the part where the bag occurred. Troubles with laminated plates have occurred before in the history of steam and marine engineering. In the making of plates, when running the metal through the rolls, slag and cinders have been known to get into the hot metal and thus prevent necessary homogeneity of the metal. That part of the plate where there is lamination is subjected to the heat of the fire on one side and air and cinder space on the other, so it gets hot enough to weaken and widen the space between it and the water side of the plate. Thus the thickness of the plate is reduced considerably and the pressure in the boiler further assists the fire on the other side to bring down the plate in the form of a bag or bulge.

Some years ago there was such an occurrence in a Scotch boiler on board ship at sea, being noticed by one of the firemen on watch at the time. It occurred in the crown sheet of one of the boilers, just a little distance in front of the bridge wall. The bag was about the size and shape of a small, old-fashioned derby hat inverted. We immediately reduced the pressure of steam in the boiler, checked the fire in that particular furnace and brought the ship to port without any further mishap.

At the point where the bulge occurred the piece of plate was cut out from the sheet and then it was discovered that the plate was laminated. There was no oil or scale in that case, nor did there need to be any, as the lamination offered the proper explanation.

Brooklyn, N. Y. CHARLES J. MASON.

Modern Plants Are Not Noisy

IN REFERENCE to Walter G. Stephan's letter, p. 271, Feb. 15 issue, I think he is in error in stating that the noise in modern power plants is so great that it is neces-

sary to yell in order to be understood. I frequently visit modern plants and my experience is that there is little disagreeable noise in such plants—usually it is a not unpleasing hum caused by the operating machinery. Visible or audible steam leaks are conspicuous by their absence. Where such noises exist, often it is not the fault of the equipment but because of the neglect of the men in charge. With old plants and badly worn equipment, of course, the case is different. Even in old plants an efficient engineer will see to it that there are no visible or noisy steam leaks at pipe joints, valve stems or other locations.

In many old plants properly operated, even the exhaust steam from return traps is used for some useful purpose and only the slight sound caused by the operation of the trap mechanism can be heard, even if a person stands close to the trap.

Some years ago, when I was engineer at the Ontario Hospital, Toronto, there was an old slide valve engine which had been doing duty for more than 50 yr. and yet it made hardly any noise at all. Where there are a lot of machines operated with iron gears no doubt there will be considerable noise, but even with ordinary babbited bearings on shaft hangers there will not be much noise if all the bearings are in proper condition. Let us be honest and place the blame where it belongs.

Toronto, Canada. JAMES E. NOBLE.

Auxiliary Heater for Fuel Oil

OCCASIONALLY there arises the need for an auxiliary heating tank for the fuel oil system particularly where the distribution lines are of considerable length and are subject to comparatively low temperatures. Such occasion presented itself at a plant where the writer had charge. The fuel oil system was designed to supply fuel oil for a large number of forge shop furnaces. The pipe lines were approximately five hundred feet long and installed openly next to the roof of a saw tooth building. During the winter, at least, the lines were exposed and although the main storage tank contained heating coils sufficient to heat the oil to approximately 125 deg., this heat was dissipated before the oil reached the burners. As a consequence the burners worked sluggishly for an hour or more until the cold oil was used out of the pipes in the early mornings.

This brought up the question of whether the oil lines should be paralleled with steam lines to keep the oil hot or whether an auxiliary heater should be installed somewhere in the forge shop. The latter method was adopted. Accordingly a 100 gal. tank was suspended from the wall in close proximity to one of the forging furnaces where the waste heat from the furnace would also assist in heating the tank.

In the accompanying figure is shown how the coil was placed in the tank. It was desired to heat the oil to a temperature of at least 100 deg. F. and the initial temperature was assumed to be 50 deg. The time of heating was taken at one hour, requiring the watchman to turn on the steam at 6 a. m. so that the oil would be warm enough to start the fires at 7 a. m. without delay. Steam pressure on the heating coil was 15 lb. per sq. in.

Fuel oil used weighed about 7.5 lb. per gal., so that the amount to be heated per hour was 750 lb. According to curves for the specific heat of oil at a temperature between 50 and 100 deg., the specific heat is 0.482. Since 750 lb. were to be heated, the total B.t.u. required was $750 \times 0.482 = 361.5$ B.t.u. per deg. Heating through 50 deg. gave 18,075 B.t.u. required.

The amount of heating surface required was determined by the formula:

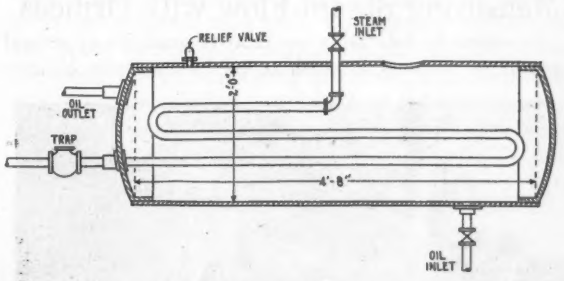
$$S = \frac{CW\,(t_1 - T_o)}{d\,U}$$

where S = square feet of heating surface required; C = specific heat of oil; W = pounds of oil; t_1 = final temperature of oil; T_o = initial temperature of oil; d = mean temperature rise; U = coefficient of heat transfer.

In this case the mean temperature rise is $50 \times 2/3 + 50 = 83$ deg.; U = 10; substituting in the above equation, we have

$$S = \frac{0.482 \times 750 \times (100 - 50)}{83 \times 10} =$$

21.75 sq. ft. of heating surface. Since 1¼-in. pipe has 2.3 sq. ft. per lineal foot, then $21.75 \div 2.3 = 9.45$ lineal ft. of 1¼-in. pipe. To give some leeway we used 12 ft. of this size of pipe.



DESIGN OF HOME-MADE FUEL OIL HEATER

If we take the latent heat in the steam at 15 lb. gage pressure, as 952 B.t.u. and the total heat required is 18,075 B.t.u., then the number of pounds of steam required will be $18,075 \div 952 = 19.0$ lb. steam per hour.

As shown in the sketch the pipe was made in a coil and inserted through the man hole in the top of the tank. This was made possible by the use of unions in the pipes so they could be inserted in halves and then coupled up from the opening. The coil was well supported in the tank to prevent possible breakage from vibration. This is important for should the coil break within the tank the oil pressure which was maintained at 40 lb. would fill the heating system. The pipe connections were made in the end of the tank.

After the tank was installed, everything went well for some time, but one day the foreman of the forge shop came in with the report that his burners were vibrating considerably and that occasionally they would go out entirely. Upon investigation it was found that the auxiliary tank had become air bound. The oil carried over some air from the main storage tank and this air was liberated in the small tank. After a time sufficient air had been carried over to begin blocking the oil outlet of the auxiliary tank, resulting in the vibration at the burners and finally causing the entire system to become air bound. This taught us that it was essential to have an air relief valve in the top of the tank just the same as at the high point of the piping system. It had been overlooked at the time of the installation of the tank.

Moline, Ill. C. C. HERMANN.

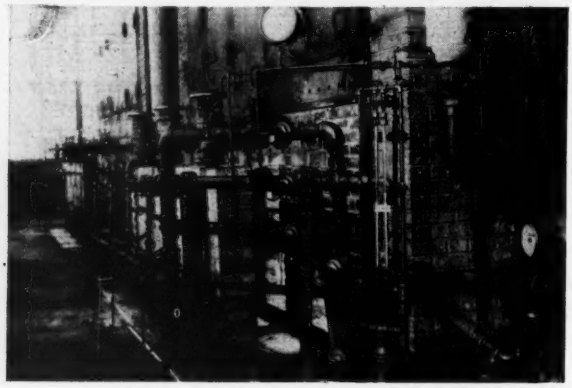
Mufflers Needed for Air Intakes

WE HAVE two air compressors operating the air lifts for our water system. Air is taken through a 5-in. pipe extending through the roof of our engine room and the noise of the suction is quite annoying to everyone in the immediate vicinity. It is becoming a public nuisance. Can any reader suggest a simple device which will overcome this trouble? H. W. K.

A. The Maxim silencer is one device used. Can readers suggest any other methods?

Measuring Steam Flow with Orifices

IN ORDER to determine the relative qualities of several types of oil burners we wish to conduct a series of tests



THIS ARRANGEMENT MEASURES STEAM CONSUMPTION OF OIL BURNERS BY ORIFICE PLATES IN A MANIFOLD

in which the steam used by each type of burner is measured. Please suggest a simple method for this.

J. E. D.

A. In the case of steam for engines, the exhaust can be condensed and weighed but with oil burners the steam must be measured before going to the burner. This may be done in a comparatively simple manner by passing the steam through an orifice plate, or rather, through a manifold which is provided with several orifice plates, so that if the load on the boiler changes from time to time and the steam to the burner is varied to suit the changes in oil consumption, the drop in pressure through the orifice can be kept at a point where the absolute lower pressure is never greater than 58 per cent of the higher pressure, absolute.

The flow of steam of a higher toward a lower pressure increases as the difference in pressure increases to a point where the external pressure becomes 58 per cent of the absolute initial pressure. Below this point the flow is neither increased nor decreased by a reduction of the external pressure, even to the extent of a perfect vacuum. The lowest pressure for which this statement holds when steam is discharged into the atmosphere or into a furnace is 25.37 lb.

For steam flowing through an orifice, from a higher to a lower pressure where the latter is greater than 58 per cent of the former, the flow per minute through thin orifices ($\frac{1}{16}$ to $\frac{1}{8}$ in. thick) may be calculated from the formula: $W = 1.9\ A\ K\ \sqrt{(P - d)\ d}$

where, W = the weight of steam discharged in pounds per minute; A = area of orifice in square inches; P = absolute initial pressure, pounds per square inch; d = difference in pressure between the two sides, pounds per square inch; K = a constant = 0.63 for a hole in a thin plate.

In the accompanying figure is shown an orifice manifold for measuring steam supplied to four oil burners under a 600-hp. boiler. There were four orifices, the diameters of which were $\frac{3}{4}$ in., $\frac{1}{2}$ in., $\frac{3}{8}$ in., and $\frac{3}{16}$ in. To the right of the manifold is shown a specially built mercury manometer for measuring the differential pressure. As the flow of steam to the burners varied, the steam was directed through that orifice or orifices which would give the least differential pressure. Usually this differential was kept at 4 to 6 in. of mercury. The initial pressure was measured with a Bourdon spring type gage, mounted above the manifold as shown in the figure.

Caustic Embrittlement in Boilers

WHAT IS meant by caustic embrittlement in steam boilers? What causes it and how may it be prevented?

C. R. B.

A. By this term is meant the embrittling and subsequent cracking of the boiler plates due to caustic solutions in the boiler water. This is usually characterized by cracks between the rivets.

Not many authentic data are available until a report of the investigations of the University of Illinois, now being carried on, is published. In the 1922 report of the Prime Movers Committee of the N. E. L. A., some valuable data are given. The salient points of this report are given herewith:

General characteristics of caustic embrittlement cases are:

(1) Occurrences ordinarily limited to the joints of the boiler.

(2) Occurrence only in parts of the boilers reached by the water. This is most noticeable in girth joints, as up to the place reached by the water (not necessarily the normal water line), cracking is found, and beyond that point the plate is unimpaired.

(3) Occurrence in the various members of the joints; that is, in the rivets as well as the plates, in both plates of a lap joint, or in plates and straps or butt joints.

(4) Occurrence in rolled plates, cast steel or cast iron, according to the construction of the boiler.

(5) When a plate is cracked the line of the crack on the surface of the plate in contact with the surface of another plate is longer than the line of the crack on the other surface of the same plate.

(6) Extreme irregularity of the cracks with sharp changes of direction; paralleling without any marked tendency to joint; in other words, the exact position of a crack is not determined by the stress due to the boiler pressure, though the general area affected may be.

(7) Brittleness of the material under shock and fatigue, with little indication of brittleness under static tests, and marked localization of the embrittlement to the joint area.

(8) Loss of embrittlement (not necessarily total), with time when the boiler is removed from service, coupled with a marked degree of removal of embrittlement by heating at temperatures far below those required for ordinary annealing.

(9) A plentiful deposit of a black powdery substance on the affected surface which on analysis is principally an iron oxide.

Since the location of cracking of this sort is selective with respect to the parts of the seams reached by the water of the boiler, reference should be made to the feed water conditions and apparently with the following considerations in mind:

(1) Solubility will be of prime importance for the reason that a highly soluble substance may be present in heavy concentration without depositing anything on the metal to protect it mechanically.

(2) These substances should not attack the metal in the concentration in which it usually occurs in a boiler, but should attack the metal in the higher concentration that can build up in restricted areas like the boiler joints.

(3) Acids can be eliminated from consideration, as they attack the entire metal surface at any concentration that could occur in boiler practice.

(4) Substances of high specific conductivity would increase the corrosive effects resulting from potential differences in the boiler structure.

(5) Substances such as calcium and magnesium carbonates or calcium sulphate, being incrusting salts and of low specific conductivity, may be eliminated from consideration for either reason alone.

Sodium hydroxide has the greatest index of solubility and conductivity. Sodium chloride is relatively low in both solubility and conductivity, and by itself is not known to be corrosive under boiler temperatures at any concentration. Magnesium chloride and calcium chloride, while higher than sodium chloride in solubility and conductivity, have hydroxides that are low in solubility, and corrosion from these substances occurs even at low concentration on all exposed surfaces.

Hydrolysis of sodium carbonate is considerable under boiler temperature and within the range of usual boiler concentration in its effect it may be regarded as though it were sodium hydroxide. Sodium sulphate will ordinarily occur in boilers as the result of the initial use of sodium carbonate, so that for all of the foregoing reasons sodium hydroxide should be considered as the most probable cause of the trouble. It is to be noted also that sodium hydroxide is only slightly corrosive at boiler temperatures in solution strengths such as occur in the main body of the water in the boiler, but is actually highly corrosive in the stronger solutions that can occur in the joints.

The cases in which this particular type of cracking has occurred can be grouped as follows:

(1) Caustic soda works where the feed water is nearly pure except for the presence of sodium hydroxide.

(2) Boilers using artesian water.

(3) Several cases in marine boilers using a compound largely made up of sodium carbonate and caustic soda.

In all of these cases sodium carbonate or sodium hydroxide appears and usually as the main substance in the water, which otherwise contains few substances. We know of no cases of this type of cracking that have been found under conditions where both of these statements were not also true.

In connection with this subject a practical question of moment is whether the use of sodium carbonate for treating feed water is likely to lead to this trouble. Nothing in the investigation work which has been thus far done indicates danger, unless the result of treatment yields a water which, from the operating point of view, has a high concentration of sodium hydroxide and almost entire absence of other substances. One experiment upon this point may be mentioned, in which all other conditions being the same, two solutions were used: one sodium hydroxide only, the other sodium hydroxide with, in addition, sodium sulphate; the embrittlement produced in a given length was in the first. When it was remembered that the natural reason for water treatment is "bad" water and that the final result of treatment is usually to leave in the water a greater excess of other soluble salts than of sodium hydroxide and as generally there will be some substances in addition that will deposit to protect the metal, there need be little fear of the result.

Cracking of this type has in more than one instance led to explosions, but it may safely be stated that it will give abundant evidence of its presence before the danger-line is reached, provided inspection of the boiler is properly made at the intervals that good operating practice requires for other purposes. The first sign of the trouble will be leakage, and if the water supply of the boiler is of the sort liable to cause trouble of this kind, and leaks are calked and do not remain tight, then a careful examination should be made. Owing to the development of the cracks in the center of the joint first, cracking can develop to quite a serious extent without making itself apparent except by leakage. Adequate inspection involves the taking out of rivets, careful cleaning of the rivet holes and, in some instances, separation of the plates to permit cleaning and examination of the joint surfaces. Such an examination is difficult and tedious, but unless done with care is valueless.

A change in the source of water supply is not usually possible. Evaporation, except in plants where the percentage of the make-up of feed water is very small, is likely to be prohibitive in cost, and the only two chemical methods of treatment so far used have their objections. One of these methods, namely, neutralization by acid, finds its objection in the risk of carelessness. The other, reaction by the introduction of magnesium sulphate, has its objection in the forming of scale.

While work already done indicates that feed waters of the class described, when concentrated in the seams of a boiler, corrode the steel and cause its embrittlement through the absorption by the steel of the resultant hydrogen, the exact manner in which the hydrogen is absorbed and the nature of the changes which take place in the steel are still uncertain.

Condensate from the World's Power Plant

ANALYZED FOR QUICK STUDY AND COMPARISON. BY WILLIAM SIBLEY

High Lights of the 1926 Prospect

The United Business Service sums up the vast amount of annual reviews and business opinions in the following manner:

"The course of business for 1926 starts with the considerable momentum derived from the speed and volume attained in 1925. To this excellent start is added the favorable influence of tax reduction and the lack of fear of unfavorable legislation. Shipping, in spite of the high levels reached during 1925, should show improvement, one of the results being improved demand for railroad equipment. Rail consolidations will also be a constructive influence.

Construction: Roads and public building will continue strong, as will small residence and farm building. A slight decline in other types of construction must be expected in most localities.

Stocks: After the long extended advance, the industrial averages appear to have discounted the best that can be expected. There may be some further strength in rails and oils, but in the absence of some unforeseen stimulus to higher prices, a slight decline is more probable than any further advance.

Commodity prices: The past year has been one of comparative stability. The general level should hold fairly strong for the next three or four months. Later we may expect a moderate decline.

Labor: Railroad labor is demanding increases, and although some believe troubles are not impossible, we expect few labor difficulties during the first half of 1926.

Foreign Trade: The relatively high level of exports is maintained by large foreign loans. These should continue, but imports are creeping up on exports and will probably exceed them before the middle of the year.

Credit: The credit situation is the weakest link in the economic chain. Unsound expansion of credits has taken place in connection with building construction, real estate speculation, and stock operations. Ultimately, these overextended credits must be liquidated—with losses.

Conclusion: Most of the bullish influences are in full operation; the further we go into 1926, the more importance unfavorable forces will take on, but business in general should continue on a relatively high level, at least during the spring months."

Vision is the World's Power Plant

Introspection calls forth retrospection. Without the perspective provided by yesterday, we cannot properly view tomorrow. It is not only fitting but necessary therefore, that we take into consideration past events before discussing present indications. This, however, can be done in one statement: *Engineering and science have assumed control.* In that statement is wrapped all the development of the past 50 yr. In it will be found deeper-going and farther-reaching effects than can be found in any other statement relating to commercial affairs. Science and engineering have taken command, with the result that we are entering upon an era of industrial expansion and activity without parallel in history. This contention is supported by evidence on every hand. Never have we had so much on the constructive side of the ledger to justify optimism. So true is this that the manufacturer, wholesaler, or retailer who does not make money during 1926 will have only himself to blame.

Let no one believe, however, that the business prosperity that is most certainly here to stay will bestow its fruits upon everyone wishing for endowment. As never before, hard work and vision are prime essentials to profit. Because science and engineering are now in the saddle, we are moving with great rapidity. The trend of today is toward simplification and unity. There is no longer a "backwoods section" of the United States; few, anywhere. The world is getting acquainted with itself. An important discovery or a vital message is known the world over 12 hr. after delivery. Discussion of world events, at the time they happen, is now commonplace.

Outside the field of communication we find all industry moving with a speed heretofore unknown. While it took hundreds of years to progress from the stage coach to the steam railroad, it took but 20 yr. to develop the automobile. Eighty years were spent in the development of the telephone; 4 yr. for the radio. In 15 yr. we not only learned how but adopted the methods whereby we could extract indigo from coal and thus almost wipe out of existence an industry that had flourished in India for a hundred years. The development of rayon has thrown thousands of Japanese silk workers out of employment and imposed a tremendous production burden on our own textile and paper industries, all in 10 yr.

Had railroad executives possessed the vision of Haynes and Ford 25 yr. ago, they would have built concrete roads along their right-of-ways, paid for them through tolls and thus capitalized their competitor, the automobile, at the same time obviating the necessity for state governments to expend enormous sums for highways which must be raised by taxation. The phonograph makers lost millions in reduced machine and record sales before they learned the wisdom of recognizing and cooperating with their competitor, radio. Electricity has outstripped manufactured gas as a utility largely because the gas men have kept their eyes glued to the kitchen range, to the exclusion of the larger opportunities in house heating and industrial usage. Criticism and protest from street-car companies failed to obviate the necessity for either serious competition or straight-forward cooperation with the motor bus. Not 10 per cent of the wood furniture manufacturers were prepared to meet the competition of steel. We move rapidly now-a-days, and the end is not yet. Hence the need for vision.

It is a trait of human nature not to visualize coming changes. We are all too prone to view tomorrow by what we know and do today. Our foresight is never as good as our hind-sight and, too often, we believe that by guiding our steps by past experience we are performing wisely. The characteristic in human nature that makes us reluctant to accept anything that may disrupt the even tenor of our ways has cost us incalculable commercial progress and uncounted years in development. In spite of all the lessons of both ancient and modern history we are wont to live and think in terms of the present. For most of us, tomorrow is a negative quantity and we therefore just sit tight

and take our chances. With emergencies arising as rapidly as they do today, this is dangerous practice.

Evidence is not lacking of the value of vision. Proof of the dollars and cents reaction from the exercise of foresight is on every hand. Mr. Hill believed in that barren expanse lying west of the Red River of the North and he built the Great Northern Railroad. The Astors and the Vanderbilts invested in Manhattan property long before the average man could dream of the extension of New York City. At the time those men started they had no more money than we; just greater foresight and willingness to take the necessary steps. The American Telephone and Telegraph Co. even now has cables stretched across the continent sufficiently large to care for increased population and demand for the next 50 yr. They realize the truth that wages are not going to come down—that building material prices will sink slightly, if at all—that what is built today will have increased value tomorrow. When radio flared into popularity, that company lost no time in securing for itself a dominating position, in its development. Because of this quick action and exercised vision the company is now so great a factor in the radio industry that it is in a position largely to shape the course of its development. No stone is left unturned in the search for inventions that may have even a remote influence on its business. It appreciates the fact that all industries are constantly becoming more and more closely related, that a development in the manufacture of one product may seriously affect a totally different product.

If we are to look ahead with vision, that we may look backward with pride, we must recognize what has gone before, alter our present position accordingly, then keep in touch with the trend of times. One cannot contemplate the increases in population, the changes in commercial activity, or the tremendously augmented demand for all commodities, without realizing that with them must come added responsibilities and the development of far-reaching improvements.

At no time in history has there been greater need for the exercise of foresight with respect to coming changes. People who are self-sufficient, who do not keep abreast of the times because of the delusion that they have the world by the tail, will likely find themselves occupying an exceedingly precarious position in the early tomorrow. Never before has it been so necessary to maintain vigilance over what is going on in the fields of science and research. Political intrigue, racial misunderstandings and unsound national ambitions cannot continue against the forces of engineering and science. In the past, those evil factors had only ignorance and human selfishness to combat, with the result that they frequently crystallized into wars. The single invention of radio will do more for the cause of universal peace than all the conferences that ever have been or ever will be. "Glorious isolation" is a thing of the past, not only in political and national circles but in business. Through engineering and science has been developed a bond of direct relationship between all industries.

In the past, developments of far-reaching importance came about slowly enough to permit of easy adjustment. Today they rise with startling rapidity and, unless we keep abreast of the trend, we shall be forced into the position of followers. "Where there is no vision, the people perish" contains more truth today than when written. Vision is the prime essential for 1926.

Why Railroad Mergers Should Be Permitted

Aside from giving an official picture of the railroad situation, the 39th Annual Report of the Interstate Commerce Commission carries two sections of particular significance; one dealing with consolidation, the other with freight traffic.

Few people realize the enormous cost of railroad operation. Equally few appreciate the costly duplication of effort and equipment that competition makes necessary. In like measure, it is only vaguely understood that in railroading, competition with its resulting duplication of equipment and expense, does nothing to better service or reduce rates. The report of the I. C. C. ably points out that the merging of competing lines would result not so much in the enhancement of stock values as in the lowering of rates and the increasing of transportation efficiency. General economy and increased efficiency would be brought about, through consolidation, because the following advantages would obtain: One set of executive officers instead of two or more; one purchasing and accounting department instead of two or more; longer trains with heavier loads, resulting in decreased cost per ton-mile; elimination of duplication of equipment and terminals, with consequent reduction in overhead; more economical routing of both freight and passengers.

The merging of railroads naturally tends toward monopoly and the majority of us have the inborn feeling that monopoly is contrary to general welfare. As a principle, when considering most commodities or services, this feeling is well grounded; but transportation is, in this respect, apart from average commodities or services. Rail transportation can be undertaken only at enormous financial outlay. Right-of-way, grading and tunnels, tracks, bridges, signal systems, stations and terminals must be acquired before a ton of freight can be moved and these items must be maintained whether 10 or 10,000 t. are moved per day. Now, if two such systems serve the same territory, all such construction must be duplicated and, since the territory yields only a given amount of traffic, rates must be high enough to pay returns on twice the amount of investment actually necessary to do the work. If competition is begun, shippers may get lower rates temporarily but only temporarily, since one of two things will arise: either one of the competitors will be ruined, in which event the shipper will face the single survivor who will immediately return to adequate rates, or a "gentlemen's agreement" will end competitive low rates.

During the Roosevelt administration, it was believed that enormous combinations of capital stifled and impeded industrial progress. We now see the fallacy of that myth, as it has been demonstrated that huge business combinations exert a beneficial influence in the reduction of production costs and retail prices, in increased ratio over smaller concerns. At the present time there are five American firms that are doing more than a billion dollars worth of business annually. There are fourteen companies having assets of more than a billion dollars, these fourteen including seven railroads, three insurance companies, one bank, one telephone company, one oil company and one steel company.

From the standpoint of the shippers (in which category all of us find ourselves) and in the interest of economy and efficiency, railroad consolidation should be a development of the next few years.

EDITORIAL COMMENT

Co-ordination of Research in Industry

In the industrial development of the first quarter of the present century, one of the most interesting features is the gradually increasing importance of research work from a purely dollars-and-cents viewpoint. Twenty-five years ago, the research worker was still regarded by the industrialist as an unpractical dreamer. It is unnecessary here to review the factors which have brought about a change in this attitude. Suffice it to say that, at the present time, the most progressive and successful companies spend vast sums of money each year in order to conduct scientific investigations into every phase of their complex and varied processes.

Results obtained by research work in various industries have been so uniformly satisfactory and have opened up such a wide field of possibilities that it has now become necessary to make some attempt to co-ordinate the work of the various research organizations throughout industry. To bring about such co-ordination, the Division of Engineering and Industrial Research has been formed by the National Research Council, which is a co-operative organization composed of representatives of national scientific or technical societies, representatives of the government and other persons whose aid may advance the objects of the Council in co-ordinating and stimulating research work in all lines.

The larger activities of this Division of Engineering and Industrial Research may be divided into two groups; promotional and administrational. The promotional activities consist of selling the research idea to industry in general, as well as to the general public, and of promoting, specifically, a program of research in certain industries which have recognized the need for it. By Division meetings of various kinds, the compilation of data and circulation of literature and the use of radio broadcasting, the Division hopes to attain the first object. By establishing contacts with various trade associations, by co-ordinating the work of research with that of the various technical societies, it hopes to be of assistance in specific cases in industry.

The solution of each new problem in research work usually opens up a number of other problems, whose existence was not suspected before, and the Division has on hand a most ambitious, but at the same time feasible, program for future progress. Problems selected for study by the Division are of broad fundamental character or are of importance to a group of industries or public utilities or to some branch of the engineering profession. The Division is interested in various investigations now going on, such as those of highways, welding, industrial lighting, fatigue of metals, marine piling and many others.

Several years of experience and evolution have crystallized the policy of the Division in regard to the research projects it undertakes. In general, it may be stated that the tendency is to sponsor fewer projects but to concentrate on those of the greatest importance to industry and to the public welfare.

Every engineer should make himself acquainted with all the details of this work and should attempt to make use of the Division whenever possible. Then, too, the engineer who is familiar with the field and scope of research work should seize every opportunity to bring it to the attention of business executives and non-technical men in industry. The results of modern research have been so conclusively displayed during the past 25 yr. that the business man who thinks he can ignore research is operating under an unnecessary and costly handicap.

Setting Standards of Power Plant Practice

Original ideas that can be used to advantage in any industry are comparatively few. They originate usually in the minds of the men most intimately connected with the work which would be improved by the adoption of the idea.

To conceive workable ideas and to put them into practicable operation are two entirely different things and in a great many instances the discoverer or inventor does not have the qualifications to push his invention to the point where it is a commercial success. The idea may be excellent but to use it technical problems may be met which the inventor cannot solve. Even when an invention has been developed into a practicable device, putting it on the market in a commercial way requires business ability and finances far beyond the reach of the inventor. For this reason best results in placing equipment on the market can be secured by an organization of men having different qualifications fitting them to carry the product through from the stage of invention to that of utilization.

Coming to equipment installed in power plants, we find progressive manufacturers advocating the use of new and commercially untried equipment guaranteeing results beyond what has previously been obtainable. Progressive engineers, recognizing the possibilities, recommend these new practices to the plant owners. The experiment, for such it probably is, looks good and the equipment goes in. If a success, the equipment usually undergoes improvements in design and becomes standard.

Inasmuch as experimenting costs money and requires engineers with specialized training, the latest or most advanced ideas will usually be found in large plants where apparently small improvements in efficiencies amount to great savings over the period of a year. The manager of a small plant can, however, benefit greatly by the experiments carried on in the large progressive plants. His problems do not have the magnitude but there are nevertheless practically the same problems of handling and burning fuel, water treatment and steam generation, steam distribution, power generation, control systems throughout the entire plant, all these problems are common to the small as well as the large plant. All the examples set by the big power plants may not be applicable in small plants but

the progressive engineer of such a plant will do well, in his endeavor to increase economy, to study the practice in modern large plants for workable advanced ideas. The larger plants thus become the laboratories where standards of practice are set and from which the smaller plants may draw their knowledge of equipment performance.

Ventilation Essential to Health and Production

That proper ventilation is of primary importance to health and efficiency is proved by the fact that a man may live three weeks without food, three days without water, but only three minutes without air. Vitiated atmosphere produces weariness, headaches and susceptibility to disease. Lowered vitality of this kind contributes to accidents, mistakes, spoilage and decreased production.

Statistics covering hospitals show a reduction of over 90 per cent in the death rate of patients in children's hospitals and nearly 75 per cent in general and military institutions, due to the installation of ventilating systems. Schools and hospitals were the first to learn that proper ventilation did not mean merely the admission of an abundance of cold air. Present standards take into consideration quality as well as quantity.

In vitiated air there is an excess of carbonic acid. This prevents sufficient oxygen from entering the lungs. On the prairies or in the country the element of carbonic acid is in the ratio of 3 parts in 10,000. When this element exceeds 7 parts in 10,000, the air is said to be vitiated and is unfit for breathing.

In factories, plants and offices where good ventilation is impossible through the opening of windows, ventilating systems adequate to care for the given spaces should be installed. Such systems are not expensive and will work definite benefits in the reduction of absenteeism, spoilage, and sickness and through increased production.

Off Duty

Several months ago the public was informed, through the medium of a series of full page advertisements in various national periodicals, of the development of a new talking machine which, it was claimed, would revolutionize the art of sound reproduction. But the public had become fed up on revolutionary developments. Between full page ravings of Florida real estate hokum and coast to coast crystal sets, the public, in spite of its native gullibility, had lost faith in the advertised panaceas and, when informed of the new phonograph, snickered up its sleeve and remarked, "So's your old man." Nobody was greatly disturbed and few took the trouble to investigate the matter. The coast to coast crystal set still left its bitter taste.

But the funny part of the story is that these announcements were true. The new phonograph *was* a revolutionary development. For many years makers of phonographs had tried to improve their product but, in spite of everything they could do, the quality of reproduction remained about the same. In appearance the phonograph underwent marked changes. The trumpet-like horn of the machine of 20 yr. ago gradually blossomed forth into the rose colored morning-glory type and, after a brief period of florescence, disappeared into the cabinet below the operating mechanism, where it has remained ever since. But the music that came out of it was still without depth or warmth.

In the meantime, the art of telephony, or the transmission of speech sounds over wires, had developed marvelously. By exact scientific method in the great research laboratories of the American Telephone and Telegraph Company and the Western Electric Company, sounds were analyzed and synthesized, electric circuits were investigated, amplifiers were developed and mathematical formulas for transmission systems evolved. Nothing was left to chance—no matter how remote from the problem at hand, each new fact, whether physical, chemical or biological was subjected to the most thorough investigation and, wherever possible, applied to the improvement of telephone communication.

It may seem that the electrical transmission of speech over wires is a problem entirely apart from the reproduction of music by means of the phonograph. But when we stop to analyze the principles involved in each of these arts, we find that they are based upon the same fundamental laws. And when the phonograph manufacturer heard of the telephone man's success, it was only natural that he should take his problem to the telephone laboratory for its solution.

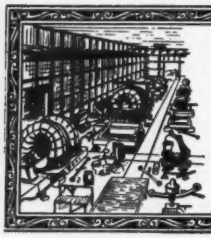
The problem was to design a mechanical system capable of transmitting speech and musical sounds from the point of the reproducing needle to the air in the room with the minimum loss in quality. The mechanical system of the existing phonographs did this very imperfectly.

For years the telephone man had been building electric circuits which would transmit currents of certain frequency and had developed formulas for determining the constants of these circuits. These formulas were handy tools and in developing the new phonograph he made good use of them. First, he examined the mechanical system of the phonograph and found that for every mechanical element he could find an electrical analog. For instance, he knew that mass could be represented electrically as inductance, mechanical force as electric pressure or voltage, velocity of motion as current, compliance as capacity. So he drew a diagram representing the record of the phonograph as a constant current generator, the needle point compliance as a condenser, the needle arm pivot as a transformer, and so on. Each element of the needle, diaphragm and horn was represented electrically. When he got through, he had a diagram of what in telephone work would be called a "filter system."

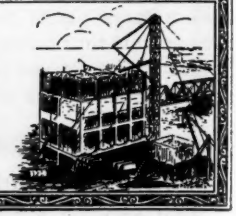
Next, he applied his formulas to the solution of this circuit and in this way determined the proper values of the electrical constants in order that it might transmit currents of the frequencies used in phonographic reproduction.

The rest of the work, although not simple, is easily explained. It was only necessary to convert the electrical quantities of the equivalent circuit into mechanical units and to use these mechanical values as the basis of design for a new mechanical reproducing system.

It would be interesting to relate how this was done, how these tiny values of mass, force, velocity were worked out, how a mechanical impedance bridge was designed which measured the mechanical impedance of a system just as easily as we measure the impedance of an electrical system, but we lack the space. The whole thing constitutes perhaps the first example of the value of exact scientific knowledge in the working out of a practical problem ever announced from a laboratory. The result? We need not discuss it, the machine speaks for itself.



POWER PLANT ENGINEERING DEVELOPMENTS AND NEWS



Philadelphia Engineers Hold Power Meeting

ONE DAY CONFERENCE HELD AT THE ENGINEERS' CLUB OF PHILADELPHIA BRINGS OUT MANY INTERESTING PAPERS DEALING WITH POWER CONSERVATION

IN ORDER to develop discussion of everyday problems in industrial plants where waste of power can be prevented and to stimulate mutual interest among the engineers whose work it is to solve these problems, there was held at the Engineers' Club of Philadelphia, on February 16th, an all day conference on the Conservation of Power in Industrial Plants. As announced in a previous issue of Power Plant Engineering, an interesting program had been arranged and a number of nationally known engineers presented papers.

Of the three sessions, the evening session was perhaps of greatest interest, particularly to those engineers concerned with the production of power in industrial establishments. At this session three papers were presented, one by Wm. A. Shoudy, consulting engineer of New York City, on "Economic Factors Governing the Purchase or Generation of Power"; another by Thomas V. Balch, supervising engineer of the Equitable Office Building, New York, on "Operating a Private Power Plant in Competition with Purchased Power" and the third, by Reginald P. Bolton, consulting engineer of New York City, on "Operating with Purchased Power in Competition with Private Power."

Naturally, the last two papers, partaking of opposite sides in the controversy over purchased power vs. private power, aroused great interest and considerable discussion. Both papers were ably presented and each of the speakers seemed to be thoroughly familiar with his respective topic.

Mr. Balch, in delivering his paper, stated that in a paper of his type there was little room for generalities and he confined himself largely to a consideration of the plant over which he has charge. The Equitable Bldg. power plant contains seven Heine water-tube boilers with a total capacity of 3350 rated horsepower arranged to burn either coal or oil. All electricity for the entire building is generated by 240-v. d.c. General Electric Co. generators direct connected to Rice and Sargent Corliss engines. Other equipment consists of house pumps, fire pumps, air compressors and refrigerating and ventilating equipment.

In operating a large plant such as this, Mr. Balch said there are two main factors to be considered, first, cooperation or to put it another way, the human factor, and second, technique, or the careful working out of all the technical detail.

The human factor is highly important and in the Equitable Bldg. everything possible is done to realize on its value. Take for instance, the comforts and conveniences provided for the men. At the Equitable Bldg., the facilities provided are essentially the same as those provided for the guests. The wash rooms, shower baths, lockers, etc., are all of marble and are kept spotless by a crew of cleaners who do nothing else. Too many office buildings and industrial plants, said Mr. Balch, are holes in the ground. At any plant where the only access is by way of an iron ladder, where every barrel taken in or out must require the use of a block and tackle, the labor problem is certain to give trouble.

The question of metering is also important and unless meters are provided to measure every commodity and unless these meters are tested and maintained accurate, the engineer will have difficulty in meeting the power salesman's argument.

The conditions in each plant vary, of course, and the operation of a private plant must be worked out for each individual case. It requires considerable study and much ingenuity. As an example of the use of the engineer's ingenuity, the method of preheating the air for combustion in the Equitable plant, as described by Mr. Balch, is of interest. This is accomplished by means of atmospheric steam in automobile type radiators installed in the ash pit doors. These radiators not only have higher capacity per unit area, a higher rate of heat transmission and lower resistance to draft than any other type of heater, but are lower in cost. These heaters installed at a cost of about $500, less than a year ago, have already paid for themselves several times over. They heat the air about 60 deg. F.

With regard to auxiliaries, Mr. Balch stated that in general it pays to replace all steam driven auxiliaries with electric motors.

In operating the Equitable building with a private plant instead of using central station current, Mr. Balch claims he effects a saving of over $100,000 a year.

Reginald P. Bolton, who presented the opposite viewpoint in his paper, "Operating with Purchased Power in Competition with Private Power," naturally was not entirely in agreement with some of the facts presented by Mr. Balch. A great deal of controversy has been expended, he said, on the unit cost in the isolated plant. Unit cost he said is not the criterion by which to judge the economic status of the private plant. The total cost of the combined service, however, is an important factor and one that should be considered.

In this latitude, Mr. Bolton stated that of all the steam used for power, only about 30 per cent is used for heating, and the claim that the private plant because of its ability to use exhaust steam for heating, is much more economical than central station power, must be questioned.

In large cities such as New York and Chicago, rental

values often more than offset the gains claimed for the private plant. In one plant, said Mr. Bolton, recently changed over to central station service, the space formerly occupied by the engine room, but now a restaurant, now brings in $12,000 a year rent.

By converting from private power to purchased power Mr. Bolton says a 400-room hotel in New York was able to save $10,000 a year. Another 300-room hotel in the same city, $22,000 a year and a 1000-room hotel in Chicago, $25,000. By the same change, a 5th Avenue department store saved $50,000 a year.

The morning session at which four papers were presented was devoted largely to a consideration of conservation in the use of power in industry. "Power Transmission Economies," presented by Wm. Staniar of the Du Pont Co., dealt largely with the problem of selection and maintenance of belting in factories. John D. Gill of the Atlantic Refining Co. next gave an interesting talk on Lubrication and Bearings, which was followed by a paper on power factor connection by Erb Dittenhofer. Mr. Dittenhofer showed how, at the plant of the Gotham Silk Hosiery Co., the power factor of the system was raised from 49.9 per cent to over 90 per cent, by the installation of static condensers. The final paper of the morning session, presented by Ward Harrison of the National Lamp Works was on the subject of plant illumination and was in many ways the most interesting paper of the session. Mr. Harrison had apparatus with him to demonstrate a number of fundamental principles of lighting as well as a short moving picture film showing the advances in illumination.

At the afternoon session, three papers were presented, one by Francis Hodgkinson on high pressure prime movers in industrial plants, another by S. M. Green on the use of exhaust steam in textile plants a third, a two-part paper by L. B. McMillan and R. H. Heilman, on the subject of heat insulation. Mr. McMillan's paper took up the savings obtainable by the use of proper insulation, while Mr. Heilman showed tables and data based on researches at the Mellon Institute, on the heat loss from pipes of various sizes and with different types of insulation.

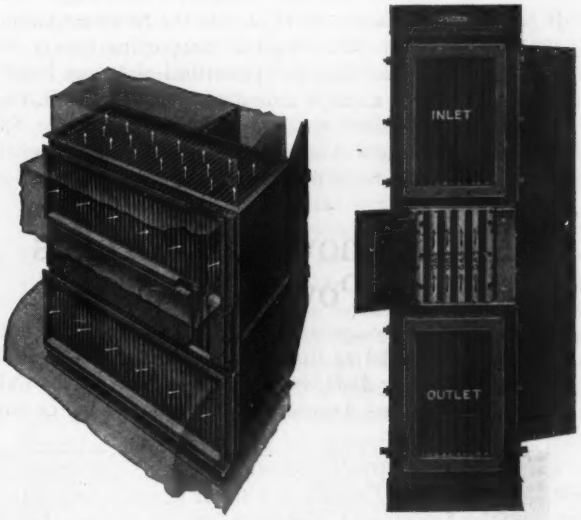
Air Economizer Uses Reversible Heating Elements

HEATED COMBUSTION AIR for steam boilers is now being used in many installations, both central station and industrial, as well as in industrial process work. A flat plate type air heater for such service, using the heat of the flue gas, and known as an Air Economizer, has recently been placed on the market by B. F. Sturtevant Co., Hyde Park, Boston, Mass. This economizer employs the counter-current principle, the air and flue gas flowing in opposite directions in alternate streams through the apparatus, separated by steel sheets so that a particle of air or gas is seldom more than ¾ in. from a heating surface.

As the rate of heat transmission through the plates varies with the temperature difference and with the velocity of air and gas over the heating surface, the passages in the Air Economizer are designed to utilize the maximum velocities obtainable and to obtain approximately equal velocities on both sides of the sheet.

It is an undeniable fact that more or less corrosion will take place on the sheets forming the heating surface. European experience with various air preheaters indicates that corrosion takes place at the cold end, the amount of corrosion depending, of course, on several operating conditions. In order to reduce the cost and facilitate replacement of the heating surface, this Air Economizer is designed with individual reversible unit chambers. This feature permits reversal of chambers when corrosion at the cold end reaches a certain point, thus increasing the life of the chambers, since little more corrosion will occur at the hot end. In addition, special steels or plates are used where conditions warrant to minimize corrosion such as in a case where the temperature of gas at the cold end approaches the dew point.

In the Sturtevant Air Economizer, sheets forming the sides of the air passages are bent over and welded, forming a chamber, the latter being spaced by distance pieces



LEFT—AIR ECONOMIZER ASSEMBLY SHOWING HOW CHAMBER IS REMOVED THROUGH REAR DOORS. RIGHT—FRONT VIEW SHOWING CHAMBERS IN PLACE

which also serve as baffles. The proper number of chambers is assembled in a structural steel frame with all inlet and outlet channels brought together on one face, as shown in the illustration. Air inlet and outlet connections are held to individual chambers by studs with a soft gasket under the connection. Sides of the frame are covered with two sheets of heavy metal enclosing insulating material and flue and fan ducts are connected at top and bottom. Chambers may be removed and replaced without disturbing any duct connections. Cleaning can be done either with soot blowers or with wire brush, steam or air lance.

P. G. & E. Co. Erecting 459-Ft. Tower

WHAT ENGINEERS say will be the highest electric transmission tower in the world is being erected by the Pacific Gas & Electric Co. as a part of the new 220,000-v. line now being built from Vaca-Dixon substation to Antioch. The record-breaker, which will be at the crossing of the Sacramento River, near Sio Vista, will be 459 ft. high, rising 30 ft. higher than the tallest skyscraper in San Francisco.

To get its line across the Sacramento and San Joaquin Rivers and at the same time comply with the Federal Government's clearance requirements for navigable streams, the company must put up five steel towers ranging in height from 269 to 459 ft., two at the Sacramento crossing and three at the San Joaquin crossing. The tallest tower of the latter span will be 359 ft.

Structural designs for the towers were made by Walter Dreyer and D. M. Robinson, company engineers, and the work of erection is being directed by E. H. Steele, who has charge of the company's line construction.

Because the lands along the rivers at the crossing sites are low, the towers have to be built unusually high. The same condition makes it necessary to drive piles 80 ft. for a foundation.

Without a splice in the wire, six copper-clad steel cables will stretch from anchorage to anchorage, 7029 ft., nearly a mile and a third, across the Sacramento, and 8835 ft. across the San Joaquin. Supporting towers will be necessary to maintain the prescribed clearance height, but there is to be a single unbroken span of 4135 ft. over the Sacramento River and one of 3175 ft. over the San Joaquin. The line will end 3 mi. south of Antioch, where the company is building its Contra Costa substation.

Model Shows California's Water Power Resources

WITH THE co-operation of the counties of the state, a relief model of the State of California 600 ft. in length and costing $100,000.00 has been built by the California Development Association, and installed in the nave

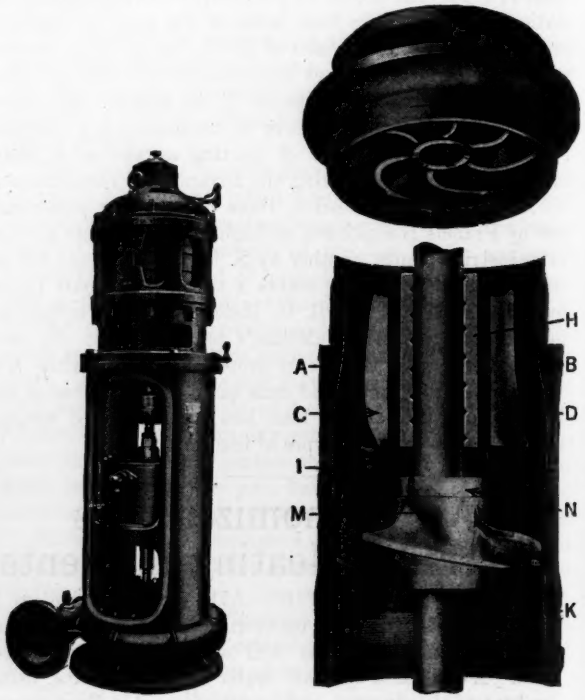
SECTION OF MODEL SHOWS TWO TRANSMISSION LINES

of the San Francisco Ferry building, where it is seen by thousands daily. The model shows the rivers, mountains, cities, railroads, highways and power transmission lines. In connection with the model interesting exhibits have been built showing the extensive resources and industries of the state such as the hydro-electric resources, oil and mining, lumber industry and the like.

The hydro-electric resources are visualized by a miniature replica of a hydro-electric power plant about 15 in. square built up in the mountains with transmission towers made in perspective and extending away in the distance to a city, showing how electric current from the power houses is distributed to the cities. The accompanying illustration shows two transmission lines in the southern part of the state. Main transmission lines were actually built of wire which extended over the mountains and through the valleys and across rivers to the various cities supplied by any particular power plant. The miniature replica of the hydro electric power plant was surrounded by cottages for the workers connected with the plant and a club house. Three lines of transmission towers (the towers being about 3 in. high) were made of copper wire exactly as the transmission lines appear and extend away to San Francisco and the Bay Cities. The outdoor bus structure is also built of copper wire, while transformers (made of wood and painted black) are placed in the usual position under the bus structure.

Axiflo and Coniflo Deep Well Pumps Have Special Impellers

HIGH COST OF water purchased from local water works has caused many plants, especially artificial ice plants, to provide their own water supply, obtaining it from deep wells. In addition to the advantages accru-



LEFT—AXIFLO DRIVING HEAD WITH DIRECT CONNECTED MOTOR AND BOOSTER. UPPER RIGHT—CONIFLO IMPELLER. LOWER RIGHT—AXIFLO IMPELLER SHOWING DISCHARGE VANES C AND D, BUSHING H AND SHELL A AND B

ing from having one's own source of supply, the water obtained from deep wells is at a relatively low temperature, with a resulting saving in refrigeration costs. Two types of rotating deep-well pumps, have been developed that are exceptionally well adapted to this service. One is known as the Axiflo and the other as the coniflo deep-well pump.

The Axiflo pump is intended for wells with casing diameter of 6 to 20 inches and even larger, in which the water level, in spite of heavy pumping, will remain within approximtaely 100 or 200 ft. below ground level. It may

also be used in wells that are too small in diameter to permit the use of the centrifugal type of pump.

Impellers of special design are used to impart an upward, constant, non-pulsating movement of the water column. As the water leaves the impellers, its upward flow has a circumferential tendency, but immediately above each impeller is a guide vane, as shown in the illustration. This guide vane converts the velocity of flow into pressure and the circumferential tendency into a true axial flow, thereby giving a constant upward flow, parallel to the axis of the pump and free from eddies and counter currents. The weight of the driving shaft is taken by a thrust bearing located in the driving head. The usual form of drive is by means of a vertical electric motor directly connected, as shown, to the pump shaft through a flexible coupling but driving heads arranged for belt drive can be supplied.

Where water is to be delivered against an appreciable head above the ground, a centrifugal booster pump is generally supplied, being built as part of the driving head. While the Axiflo pump is capable of delivering water against an above-ground head, the use of a centrifugal booster pump enables greater efficiency and economy to be obtained.

The Coniflo pump is suited for depths as great as 400 ft., has a greater head per stage than the Axiflo pump but is not capable of delivering as great a volume of water from a well of given size and depth as the Axiflo pump. It is accordingly recommended for wells over 150 ft. deep, where the number of impellers required on a pump of the Axiflo type would become excessive. Impellers of the Coniflo pump are conoidal in shape as shown. This design effects a true combination of the axial-flow principle with the radial flow principle of the centrifugal type of deep-well impeller. The result is a high head per stage combined with the ability to deliver large quantities of water.

Driving heads are furnished for direct-connected vertical motor or belt drive. A booster pump, built into the driving head, can also be supplied. The Axiflo and Coniflo pumps are manufactured by The Worthington Pump & Machinery Corp., Deane Works, Holyoke, Mass.

THREE RESEARCH fellowships in the Institute of Research, Lehigh University, Bethlehem, Pa., have recently been announced. Appointment will be made on or before the first of June, 1926. One fellowship in science and technology is provided by endowment by the New Jersey Zinc Co. The annual stipend is $600 and half the time of the holder of this fellowship must be devoted to research work in the field of science or technology to which he is assigned; the other half to graduate study leading to the degree of Master of Science.

Two Henry Marison Byllesby research fellowships in engineering will be appointed as provided for by an endowment given by the widow of Col. Henry M. Byllesby. The annual stipend of these fellowships is $750 and half the time of the holders must be devoted to research work on some problem in electrical, mechanical or hydraulic engineering proposed by the president of the Byllesby Engineering & Management Corp. Applications for these fellowships must be submitted before May 1, 1926.

CONTINUAL FIGHT with boiler scale is the penalty of improper feed water treatment.

Great Western Power Co. to Spend $11,558,000 in 1926

THE GREAT WESTERN POWER CO. of California will spend during the year of 1926 the sum of $11,558,000 in the operation of its properties and for new construction projects, according to a recent announcement by J. B. Black, vice-president and general manager of the company.

New construction work now in progress, or to be commenced during the year, will cost $8,611,000. A careful study of load conditions and production and distribution facilities has resulted in a program of development which will put the Great Western Power Co. in an excellent position to meet the ever-increasing demand for service in all parts of its territory.

At a cost of approximately $2,000,000 the Big Meadows dam in Plumas county is being raised 45 ft., and its thickness extended from 600 to 1250 ft., increasing the capacity of Lake Almanor from 300,000 acre-feet to 1,300,000 acre-feet.

This work includes the construction of a giant concrete spillway, an outlet conduit beneath the dam to permit the drawing off of water into the Feather River below, and an electrically operated outlet tower.

Lake Almanor, already the largest artificial power reservoir in the world, will then have a capacity greater than that of all others in the state of California combined. Rapid progress is being made in this work, and it is expected that the run-off during the 1926-27 winter season will be stored behind the enlarged dam.

An additional $2,000,000 is required for the construction of a 220,000-v. steel tower transmission line between Brighton substation, near Sacramento, and Merced, interconnecting the Great Western Power system with that of the San Joaquin Light and Power Corporation, and making available in the great San Joaquin valley power generated from water stored in the Lake Almanor. This line will be 104 mi. in length and will carry ultimately two three-wire circuits, operating at 220,000 v., but will initially be operated with one circuit.

The new Wilson substation, which will be built at the southern terminus of the tie line, will cost an additional $700,000. This substation will be equipped with modern self-cooling transformers having a capacity of 60,000 kv.a. and a condenser whose capacity is 25,000 kv.a. The construction of this connecting link is considered one of the greatest economic feats in the development of California's power resources.

A new automatic substation will be erected at Isleton and interconnected with the company's two large substations at Brighton and Oakland. The cost of this substation will be $206,000. Transformers having a capacity of 9000 kv.a. will be installed, providing ample facilities to care for the rapid load growth in the island territory.

An extension to the present Fourth Avenue substation in Oakland and the addition of new transformers and switching apparatus calls for an expenditure of $150,000 and the installation of an additional bank of transformers at Golden Gate substation will require $50,000.

Miscellaneous additions and betterments to the company's distributing substations will cost $1,350,000 and the construction of new distribution lines during the year throughout the company's entire territory is estimated at

$1,500,000. The 1926 budget calls for an expenditure of $2,947,000 for the operation of the company's production, transmission and distribution system, taxes, etc.

Future Trends in the Power Industry

PROBABLE developments in the power industry during the coming 5 yr. was the subject of discussion at a meeting of the Metropolitan Section, A.I.E.E., held in New York on January 29. Different aspects of the subject were presented by four speakers, each qualified by his achievements in a particular branch of the industry. The discussion was based for the most part upon predictions made in prize-winning essays submitted last year in the contest conducted by Bonbright & Co., New York.

Of greatest interest to engineers were the views expressed by Horace P. Liversidge, vice-president of the Philadelphia Electric Co., in relation to the technical aspects of the subject. Power plant designers, he said, will be called upon for increasing efforts toward reducing capital outlay and increasing efficiency; for the selling price of the product will probably remain constant or go down, while most of the materials which power companies must buy tend to rise steadily in cost.

The directions which efforts at technical improvement must take in order to help most in meeting future demands, Mr. Liversidge listed as follows:

(1) Economy of conversion from fuel to electric power;

(2) Lower capital cost for plant extensions;

(3) Reliability.

Improvements under the first or last heads will naturally be reflected in a reduction of capital outlay required for plant extension. Reliability is at present important, not because of its relation to the customer, since breakdowns are extremely rare, but increased reliability will reduce outlay for standby equipment, for repairs and for inspection; it is this indirect saving which more reliable machinery may effect.

As regards economy, by 1930 it is likely that the standard for new installations will be about 1 lb. of coal per kw-hr. or 13,500 B.t.u. per kw-hr.

Steam pressures of 1200 lb. per sq. in. should be in use rather widely by 1930, but it is unlikely that there will be any tendency to exceed that figure.

Pulverized fuel will be the common practice but not to the exclusion of stokers. Relative costs will often show in favor of the latter. Large stoker installations now being made are planned with a view to possible future substitution of pulverized fuel.

The largest single plant in 1930 will not exceed 800,000 kw. and probably will be substantially smaller than that. Single units will not continue to increase in size, as they have in recent years. No increase in unit cost of efficiency can be effected by going to sizes larger than about 60,000 kw. Instead, future development should tend toward increased speed as a means of reducing cost. The typical large unit in 1930 will be about 80,000 kw. at 85 per cent power factor, running at 1800 r.p.m. and mounted on a single shaft.

The mercury boiler is not likely to have become an important factor by 1930, though it may by that time be showing great promise for the following decade. In distribution there is great opportunity for improvement but developments occurring before 1930 will not have a marked influence until the following years. The present maximum voltage for long lines is 220,000 v. and this is adequate for transmission 300 mi. No development before 1930 is likely to require more than this, except as some unforeseen special case may occur.

Underground transmission for cities or populous districts shows great promise. A cable for this use already on order will operate at 132,000 v. Similar cables should meet any requirement likely to arise during the 5-yr. period.

Transforming and switching apparatus should advance rapidly The capital outlay now required for this and other distribution equipment is disproportionate. By 1930 transformers of 100,000 kv-a. capacity should be operating. The interrupting capacity of switching equipment will not much exceed the present limits, as reactive effects should be used to diminish the capacity needed.

Interconnection or super power presents disadvantages as well as advantages. It improves reliability and reduces standby requirements. Also, it would make possible many hydroelectric developments which at present would not be economical; but the great cost for capital, the carrying charges and maintenance will hinder progress.

Closing his summary, Mr. Liversidege said that all growth in the industry will depend upon advances in engineering and management for economy is the prime factor of importance. Output may continue increasing indefinitely, provided it can be produced at the low figure essential for profitable marketing.

John F. Gilchrist, vice-president of the Commonwealth Edison Co., Chicago, discussed future commercial and sales prospects. Future efforts should be toward greater use by the individual customer, rather than toward finding more customers. The number of customers has already nearly reached a saturation point and will now increase in proportion to population. But almost any customer can use to advantage far more appliances than he now does. Refrigeration is the most promising field of domestic use, while industrially, chemical and metallurgical processes using electric heat will have rapidly increasing application.

Robert M. Davis, statistical editor for the Electrical World, who won second prize in the Bonbright essay contest, showed interesting tables and diagrams of the power industry's growth.

H. V. Bozell, of Bonbright & Co., explained methods of financing and emphasized the value of the holding company in stabilizing the industry.

ARRANGEMENTS are being made for a consolidation of the Rockland Light & Power Co., Nyack, N. Y.; Orange County Public Service Co., Middletown, N. Y.; and Catskill Power Corporation, operating in this same section, under the name of the first noted organization. The new company will be capitalized at from $10,000,000 to $15,000,000, and proposes early expansion in existing combined facilities. This work will include the construction of a new hydroelectric generating plant on the Mongaup River and the building of a transmission line from this point to the Orange and Rockland County districts. The cost is reported in excess of $1,000,000. Millard F. Clement is general manager of the Orange County Co.

News Notes

THE SUPERHEATER Co. of New York and Chicago recently elected M. Schiller vice-president in charge of accounts and purchases and W. F. Jetter, treasurer and assistant secretary. Bard Browne was appointed assistant to vice-president in charge of sales and service, and T. F. Morris, assistant secretary and assistant treasurer. Mr. Schiller joined the company in 1910 when it was organized as the Locomotive Superheater Co. and has served in various administrative and executive capacities. Mr. Browne came with the company in 1914 and has been actively identified in the application of locomotive superheaters and feed-water heating devices, serving in various engineering, sales and service capacities.

HERMAN STEINKRAUS has recently assumed the representation of Bridgeport Brass products in the Cleveland territory. Mr. Steinkraus has handled sales and organization work in managerial capacities for the Cleveland Automatic Machine Co., the Cleveland Chamber of Commerce, the Advertising Club of that city and the National Secretary's office of the National Young Men's Business Clubs. This last eight years have been spent with the Osborn Mfg. Co., from which he resigned not long ago as general sales manager.

ALLIS-CHALMERS business in Continental Europe will be handled through an organization recently incorporated as Allis-Chalmers (France), with headquarters at 3 rue Taitbout, Paris. H. I. Keen, who has been manager of European sales through the company's district office in Paris, will be the managing director of the new organization. The company has maintained for many years an office in London, 728 Salisbury House, London Wall, F. C. 2.

THE UNITED FUEL GAS Co., Charleston, West Virginia, has placed an order with the Worthington Pump and Machinery Corporation for four 22-in. by 36-in. twin tandem double-acting gas engines and for three 22-in. by 36-in. tandem double-acting gas engines.

All seven engines are to be arranged for gas compressor drive.

HOMESTEAD VALVE MANUFACTURING Co., Homestead, Pa., announces that the Smith Separator Co., Chestnut & Smith Corp. Bldg., Tulsa, Okla., has been appointed agent for the Homestead line in the states of Oklahoma and northern Texas. Finney & Fuller Co., 147-149 Hotel St., Utica, N. Y., has been appointed agent in the Utica district.

KIELEY & MUELLER, INC., New York City, has granted the exclusive agency for their products in the states of Missouri, Kansas, and the southern half of Illinois to the Reeves & Skinner Machinery Co. of 2211 Olive street, St. Louis, Mo.

THE DIAMOND Power Specialty Corporation announces the appointment of J. E. Heeter as manager of the Philadelphia office. Mr. Heeter succeeds M. J. Miller, who has been transferred to the Detroit territory.

DEVELOPMENT costing about $6,000,000 of which $200,000 would be for a plant at Windsor Locks, Conn., was proposed in a petition filed with the Public Utilities Commission of Connecticut, which was given a hearing before that commission recently. The hearing was on request of six Connecticut power companies to merge under the name of the Northern Connecticut Power Co. These companies are the Connecticut River Co., the Northern Connecticut Light & Power Co., the Thompsonville Water Co., the Stafford Springs Aqueduct Co., Northern Connecticut Power Co. and the Somers Electric Co. Control of all of these companies was recently acquired by the J. G. White Engineering Co. of New York City. Plans call for construction of a hydro-electric plant at the Windsor Locks Canal which would greatly increase the amount of power available. Already many industries in the territory served have asked for current but so far have been unable to secure it owing to present limited output.

HARRY S. SCHANCK announces he has established his own office at 50 Church St., New York City, and will make a specialty of pumping problems.

Book Reviews

MECHANICAL WORLD YEAR BOOK, 1926 edition, has just been received from Emmott & Co., Ltd., Manchester, England. The present edition includes a new section on the Uniflow engine, one on grinding with many tables and data on allowances, abrasive and the like, the others on forced and shrinkage fits and on chains and ropes for lifting. The section on superheating has been rewritten and a new section on fuel economizers has been introduced.

BULLETIN No. 152 of the Engineering Experiment Station of the University of Illinois is the fourth report of the progress of an investigation of the fatigue of metals carried on at the University of Illinois in cooperation with the National Research Council, the Engineering Foundation, and several manufacturing firms. Previous reports are given in Bulletins Nos. 124, 136 and 142. It deals with the following subjects: (1) fatigue strength and static strength of steel at elevated temperatures, (2) the effect on fatigue strength of stress intensification at a small hole, (3) magnetic analysis as a test for fatigue strength of steel, (4) fatigue strength of non-ferrous metals, (5) fatigue strength of case-carburized steel, (6) testing machines for repeated stress, and (7) miscellaneous test results for metals. Copies may be obtained without charge by addressing the Engineering Experiment Station, Urbana, Ill.

INDUSTRIAL WATER SUPPLIES OF OHIO, by C. W. Foulk, Professor of Analytical Chemistry, The Ohio State University. Cloth, 7 by 9 in., 406 pages, 20 tables. Price $1.00, Columbus, Ohio.

This book, issued as Bulletin 29 of the Geological Survey of Ohio under the supervision of the state geologist, was prepared primarily as a study of the waters of the state but it would seem to have wide interest on account of the discussions of general water supply problems and methods of solving them. The topics are presented in their general scientific aspects rather than along strictly engineering lines. Though some of it is necessarily technical, the author has kept in mind owners of mills and factories, engineers other than chemical engineers, and even young people with some training in elementary chemistry.

Part I of the book takes up first a discussion of general information about water and its use, substances found in it and changes taking place in it. It then takes up water analyses and methods of interpreting them. Chapters on methods of chemical analysis, scale, boiler

compounds and internal treatment and corrosion are given, together with one on foaming and priming. Of special interest is the chapter on purification for industrial use, discussing some of the well-known commercial methods.

Parts II and III, which are of particular interest to residents of Ohio, consist mostly of tables showing analysis of water samples of both surface and ground water, taken at hundreds of points in Ohio.

STUDIES OF BOND BETWEEN CONCRETE AND STEEL, by Duff A. Abrams, has been issued as Bulletin 17 of the Structural Materials Research Laboratory of Lewis Institute, Chicago. It describes the materials and tests used in the investigations and presents the results in graphs and tables. Effect of Size and Shape of Test Specimen on Compressive Strength of Concrete, by Harrison F. Gonnerman, has been issued by the same laboratory as Bulletin 16. This bulletin describes the tests and, as a result of them, concludes that the 6 by 12-in. cylinder generally used, as recommended by the A. S. T. M., is a satisfactory specimen for aggregates 2 in. or less in diameter. For all forms of specimens the compressive strength increased with age for moist curing.

TECHNICAL PAPER No. 320, which has just been issued by the U. S. Bureau of Mines, gives a description of the modification of the Orsat apparatus as used in the Bureau for analysis of gases. This paper describes apparatus used for the complete and partial analysis of gases. A complete analysis—including carbon dioxide, illuminants, oxygen, carbon monoxide, hydrogen, methane, and ethane—can be made without connecting or disconnecting any parts. Since all other constituents are removed before the paraffin hydro-carbons are burned, larger amounts of the paraffins may often be taken for combustion with oxygen, and more accurate determinations of methane and ethane can thus be obtained. The same argument holds true for hydrogen and carbon monoxide, which are determined by fractional combustion with copper oxide at 300 deg. C. Either mercury or water may be used as the confining liquid in the burette, depending on the accuracy desired.

As the Bureau of Mines has received many inquiries regarding gas-analysis methods used in its laboratories, this description of the Orsat apparatus it now uses is published in response to those inquiries.

BULLETIN No. 151, entitled "A Study of Skip Hoisting at Illinois Coal Mines," by Arthur J. Hoskin, has been issued by the Engineering Experiment Station of the University of Illinois. In considering the merits of skip hoisting, comparison must be made with cage-hoisting practice. Among the advantages usually claimed for skip hoisting are: greater capacity per mine shaft, easy enlargement of hoisting capacity to provide for expanding production, lower power consumption, lower power and labor cost per ton, for similar outputs smoother hoisting cycles and lower rope speeds, the use of solid-end mine cars, a larger ratio of coal to gross load hoisted, and reliability of dumping of coal in tipple. Some of the disadvantages claimed are: more expensive hoisting installations, greater breakage of coal, complication in the handling of men, materials, and waste, difficulty of any systematic inspection of coal for docking, and production of obnoxious dust by double dumping of run-of-mine coal at the shaft bottom.

The bulletin was written as the result of an investigation into the validity of these claims. One or two items were easily verified, while the verification of others called for data that were either impossible or difficult to obtain. It is believed, however, that tentative opinions can be expressed which will enable a mine operator the better to decide for himself the merits of skip hoisting under his own conditions. Copies of Bulletin No. 151 may be obtained without charge by addressing the Engineering Experiment Station, Urbana, Ill.

Catalog Notes

CHAS. CORY & SON, INC., New York City, has devoted its bulletin No. 104-29-B to the Cory audible and visible signals featuring the turbine order systems.

COMBUSTION ENGINEERING CORP., New York, has recently issued its catalog FF-1 dealing with C-E fin furnace which is a water-cooled furnace designed to eliminate wall maintenance and increase boiler efficiency.

"METALLO GASKETS" is the title of catalog No. 26 recently issued by Metallo Gasket Co. of New Brunswick, N. J. This catalog is prepared to help the users of gaskets giving descriptions of various types of gaskets for special purposes and tables of sizes available.

CLARAGE NEW type FD blowers are announced in bulletin No. 311, recently issued by the Clarage Fan Co., Kalamazoo, Mich. This blower is designed especially for furnishing forced draft and operating at high speed, thus making it suitable for direct connection to either steam turbines or electric motors.

"COMBUSTION STEAM GENERATOR" is the subject of a bulletin recently issued by the Combustion Engineering Corp. of New York. This generator is described as a revolution in steam generation because of the small amount of space occupied by the furnace and the radical departure in design from present-day types of boilers.

AMERICAN DISTRICT STEAM CO., North Tonawanda, N. Y., has recently issued bulletin No. 184 dealing with the St. Johns steam flow meter, bulletin No. 192 describing the Adsco rotary condensate meter, which is a new product of the company, and bulletin No. 193 describing the Adsco Simplex condensation meters.

"MEASUREMENTS OF WATER" is the subject treated in bulletin W-31 recently issued by the Republic Flow Meters Co. of Chicago, Ill. This bulletin goes into the principles of water measurement as applied in Republic flow meters and devotes some space to a discussion of the value of the water meter for various purposes and shows the results obtained in several installations.

DEXTER VALVE reseating machine, as manufactured by the Leavitt Machine Co. of Orange, Mass., is described and illustrated in the new catalogue, No. 23, which has recently been sent out by the company. The details of the valve reseating machine and what it accomplishes, as contrasted to the results from regrinding only, are fully explained and the action of the machine is shown in the illustrations. Different types of machines are shown for globe valves, gate valves and pump valves; also a convenient device for cutting a recess below the valve seat which will further extend the life of the valve. It is worth while noting that the reseating of the valve to take out deep cuts and pits is quite a different thing from regrinding to take care of minor leaks and also that it is well worth while to have valves kept at all times in perfect condition, so that leakage will be avoided.

Sparks from the Advertising Pages

Where Buyers and Sellers Meet

Masters of Human Destinies

Observe the march of man from prehistoric times to the present and we see the forces in the panorama of progress that shape destinies of races, peoples and individuals.

From the fastnesses of caves and mountain-side strongholds, men came into the lowlands and there built up civilizations made possible by the wealth of the soil.

Beast-borne caravans traversed plains and mountain passes, but for their centers of activity, mankind clung close to the banks of waterways.

Then came mechanical power and there followed greater development and wider applications of countless inventions that had been limited through the centuries by lack of power except that of men and animals to work them.

At first concentration in established centers followed the use of mechanical power. Enormous industrial works grew up in the space of a short time, and this power derived from fuels seemed to have brought many disadvantages to the race of man as well as advantages.

It hindered man's growth in the art of living, both in the class of men to whom it brought great wealth and in the mass of men who applied its energy to the creation of multitudinous products.

Again, as in all historic crises, the inescapable laws of natural development obtained, and as power-built products piled up, a new order of things dawned for mankind.

Just as dynastic governments or other concentrations of power over people cannot exist indefinitely except by the will of the people, so industrial, mercantile, financial and other concentrations of material things, burst the bounds of personal and group domination and spread like a vast, beneficent diffusion of life-giving waters over the whole country and to the roots of every life.

In this new era we are just entering, we can see wealth in its many forms and control of these forms passing into the hands of the great majority of the people.

In comparison with this new movement, there never existed on this earth so great a mastership of man over the elements, the works of his kind and over his own destiny as that of today.

Backed by the certain strength of mechanical power in their work, more men own more of industry than ever before.

Millions of workers find the way made easy for them to own an interest in the enterprises for which they work and in the enterprises which serve them with power, heat, light, transportation and other necessities.

Just as it is impossible to try a whole people for treason, so it has become impossible to shut down industry, create a financial panic or bring about hard times in a nation where workers, customers, owners and controllers are all one class.

Out from the strongholds of industry, mankind moves by the magic of power to play and to live far from the appointed places of work.

Out from the limited choice of work of past generations, men move toward ever broadening opportunities, unhampered by tradition, geographic position or lack of education.

Out from under the countless minor cares of attending to personal needs, all mankind, dwelling in hills or plains, in the country or in cities, moves into the leisure and security of new conveniences and comforts.

Men, machines and devices engaged in power generation are mighty factors in the life and work of great groups of men.

They are today's masters of destinies.

Machinery, Equipment and Supplies Used In The Production and Transmission of Power

Under the heading of each product listed will be found the names of the manufacturers of that product. The index to advertisers, next to the back cover, gives the page numbers on which the manufacturers' descriptive advertisements appear.

AIR COMPRESSORS.
Allen & Billmyre Co., Inc., New York.
Allis-Chalmers Mfg. Co., Milwaukee, Wis.
American Steam Pump Co., Battle Creek, Mich.
Bethlehem Shipbuilding Corp., Bethlehem, Pa.
Dean Bros. Co., Indianapolis.
De Laval Steam Turbine Co., Trenton, N. J.
Gardner Governor Co., The, Quincy, Ill.
Ingersoll-Rand Co., New York.
Murray Iron Works Co., Burlington, Iowa.
Nordberg Mfg. Co., Milwaukee.
Worthington Pump & Machinery Corp., New York, N. Y.
Yeomans Bros Co., Chicago.

AIR FILTERS.
Allen & Billmyre Co., Inc., New York.
Cooling Tower Co., Inc., The, New York.
Spray Engineering Co., Boston.

AIR WASHERS.
Badger & Sons Co., E. B., Boston, Mass.
Cooling Tower Co., Inc., The, New York.
Spray Engineering Co., Boston.

ALARMS, HIGH AND LOW WATER.
Hills-McCanna Co., Chicago.
Huyette Co., Inc., The Paul B., Philadelphia.
Northern Equipment Co., Erie.
Wright-Austin Co., Detroit.

ARCHES, BOILER AND COMBUSTION.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Brady Conveyors Corp., Chicago.
Burke Engineering Co., Holland, Mich.
Detrick Co., M. H., Chicago.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Hofft Co., The M. A., Indianapolis, Ind.
Liptak Fire Brick Arch Co., Mexico, Mo.
McLeod & Henry Co., Troy, N. Y.
Obermayer Co., The S., Chicago.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., New York.

ASH BIN GATES AND DOORS.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
Brady Conveyors Corp., Chicago.
Conveyors Corp. of Amer., Chicago.
Hagan Co., George J., Pittsburgh.

ASH HANDLING SYSTEMS.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
Brady Conveyors Corp., Chicago.
Conveyors Corp. of America, Chicago, Ill.
Detrick Co., M. H., Chicago.
Hagan Co., George J., Pittsburgh.
Link-Belt Company, Chicago.
Stearns Conveyor Co., The, Cleveland, Ohio.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.
Weller Mfg. Co., Chicago, Ill.

ASH TANKS
Conveyors Corp. of America, Chicago.
Hagan Co., George J., Pittsburgh.

BABBITT METAL.
Magnolia Metal Co., New York.

BEARING METAL.
Magnolia Metal Co., New York.
Strong, Carlisle & Hammond Co., Cleveland, Ohio.

BEARINGS.
National Tube Co., Pittsburgh.

BELT CONVEYORS.
Stearns Conveyor Co., The, Cleveland, Ohio.
Stephens - Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.
Weller Mfg. Co., Chicago, Ill.

BELT DRESSING.
Cling-Surface Co., Buffalo, N. Y.
Dixon Crucible Co., Jos., Jersey City, N. J.
Standard Oil Co. (Indiana), Chicago, Ill.
Stephenson Mfg. Co., Albany.

BELT LACING.
Bristol Co., The, Waterbury.

BELTING.
New York Belting & P'k'g Co., New York.
Quaker City Rubber Co., Philadelphia.
United States Rubber Co., New York, N. Y.

BELTING, SILENT CHAIN.
Link-Belt Co., Chicago, Ill.
Morse Chain Co., Ithaca, N. Y.

BLOWERS, FAN & FURNACE.
Air Preheater Corp., The, New York.
Coppus Engineering Corp., Worcester, Mass.
De Laval Steam Turbine Co., Trenton, N. J.
Ingersoll-Rand Co., New York.
Terry Steam Turbine Co., Hartford, Conn.
Wing Mfg. Co., L. J., New York.

BLOWERS, FORCED DRAFT.
Sturtevant Co., B. F., Hyde Park, Mass.

BLOWERS, PORTABLE.
Allen & Billmyre Co., Inc., New York.
Sturtevant Co., B. F., Hyde Park, Mass.
Marion Mach., Fdry. & Supply Co., Marion, Ind.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.
Vulcan Soot Cleaner Co., Du Bois, Pa.
Webster, Howard J., Philadelphia, Pa.

BLOWERS, STEAM.
Schutte & Koerting Co., Philadelphia.

BLOWERS, TURBINE.
Allen & Billmyre Co., Inc., New York.
Moore Steam Turbine Corp., Wellsville, N. Y.
Wing Mfg. Co., L. J., New York.

BOILER BAFFLES.
Betson Plastic Fire Brick Co., Rome, N. Y.
Johns-Manville, Inc., New York.
McLeod & Henry Co., Troy, N. Y.
Quigley Furnace Specialties Co., Inc., New York.

BOILER CAP CLEANERS.
Lagonda Mfg. Co., Springfield, Ohio.

BOILER CASING.
Walsh & Weidner Boiler Co., The, Chattanooga, Tenn.

BOILER COMPOUND.
Botfield Refractories Co., Philadelphia, Pa.
Dearborn Chemical Co., Chicago.
Hawk-Eye Compound Co., Blue Island, Ill.
McLeod & Henry Co., Troy, N. Y.
Paige & Jones Chemical Co., Inc., New York.

BOILER COMPOUND FEEDERS.
Hills-McCanna Co., Chicago, Ill.

BOILER COVERINGS.
Celite Products Co., New York.

BOILER FEED WATER PURIFYING APPARATUS.
Griscom-Russell Co., New York.
Paige & Jones Chemical Co., Inc., New York.
Permutit Co., New York, N. Y.
Power Plant Specialty Co., Chicago, Ill.
Scaife & Sons Co., Wm. B. Pittsburgh.

BOILER FRONTS.
McLeod & Henry Co., Troy, N. Y.

BOILER MOUNTINGS.
Lunkenheimer Co., Cincinnati.

BOILER SETTING CEMENT.
Betson Plastic Fire Brick Co., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
Huyette Co., Inc., The Paul B., Philadelphia.
Obermayer Co., The S., Chicago.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., New York.

BOILER SETTINGS.
Betson Plastic Fire Brick Co., Inc., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison-Walker Refractories Co., Pittsburgh, Pa.
McLeod & Henry Co., Troy, N. Y.

To Find the Manufacturers' Advertisements of Products Listed Here, See Index Page 162

BOILER SKIMMERS.
Sims Co., The, Erie, Pa.

BOILER TUBE CLEANERS.
Lagonda Mfg. Co., Springfield, Ohio.
Liberty Mfg. Co., Pittsburgh.
Pierce Co., The Wm. B., Buffalo, N. Y.
Roto Co., The, Hartford, Conn.

BOILER TUBES.
Babcock & Wilcox Tube Co., The, Beaver Falls, Pa.
Bethlehem Steel Co., Inc., Bethlehem, Pa.
Murray Iron Works Co., Burlington, Iowa.
National Tube Co., Pittsburgh.
Reading Iron Co., Reading, Pa.
Scully Steel & Iron Co., Chicago.

BOILER WALL COATINGS.
Botfield Refractories Co., Philadelphia, Pa.

BOILER WALL COVERINGS
Johns-Manville, Inc., New York.

BOILERS.
Babcock & Wilcox Co., N. Y.
Badenhausen Corp., Cornwells Heights, Pa.
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Edge Moor Iron Co., Edge Moor, Del.
Heine Boiler Co., St. Louis.
Kingsford Fdry. & Mach. Wks., Oswego, N. Y.
Murray Iron Works Co., Burlington, Iowa.
Nuway Boiler & Engineering Co., Chicago.
Union Iron Wks., Erie, Pa.
Vilter Mfg. Co., Milwaukee.
Walsh & Weidner Boiler Co., The, Chattanooga, Tenn.
Webster, Howard J., Philadelphia, Pa.
Wickes Boiler Co., Saginaw.

BOOKS AND SCHOOLS.
McGraw - Hill Book Co., Inc., New York.

BREECHINGS.
Littleford Bros., Cincinnati, O.

BRICKS, FURNACE LINING.
Norton Co., Worcester, Mass.

BRUSHES, DYNAMO AND MOTOR.
Calebaugh Self-Lubricating Carbon Co., Inc., Philadelphia.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, GRAPHITE.
Dixon Crucible Co., Jos., Jersey City, N. J.

BRUSHES, WIRE.
Pilley Pkg. & Flue Brush Mfg. Co., St. Louis, Mo.

BUCKET ELEVATORS.
Link-Belt Company, Chicago.
Webster Mfg. Co., The, Chicago.

CAR DUMPERS.
Wellman - Seaver - Morgan Co., The, Cleveland, Ohio.

CARRIERS, PIVOTED BUCKET.
Webster Mfg. Co., The, Chicago.

CASTINGS.
Bethlehem Steel Co., Inc., Bethlehem, Pa.
Fuller - Lehigh Co., Fullerton, Pa.
Hills - McCanna Co., Chicago.
Neemes Fdry. Inc., Troy, N. Y.

CEMENT, ASBESTOS.
New York Belting & P'k'g Co., New York.

CEMENT, FURNACE.
Betson Plastic Fire Brick Co., Rome, N. Y.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh.
McLeod & Henry Co., Troy, N. Y.
Norton Co., Worcester, Mass.
Queen's Run Refractories Co., Inc., Lock Haven, Pa.
Quigley Furnace Specialties Co., Inc., New York.

CEMENT, HIGH TEMPERATURE.
Botfield Refractories Co., Philadelphia, Pa.
General Refractories Co., Philadelphia, Pa.
Harbison - Walker Refractories Co., Pittsburgh, Pa.
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Norton Co., Worcester, Mass.
Obermayer Co., The S., Chicago.
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Smooth-On Mfg. Co., Jersey City, N. J.

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Babbitt Steam Specialty Co., New Bedford, Mass.

CHAINS, DRIVE.
Link-Belt Company, Chicago.
Morse Chain Co., Ithaca, N. Y.

CHIMNEYS.
American Chimney Corp., New York.

CIRCUIT BREAKERS.
Cutter Co., The, Philadelphia.

CLEANERS, BOILER TUBE.
General Specialty Co., The, Buffalo, N. Y.
Lagonda Mfg. Co., Springfield, Ohio.
Liberty Mfg. Co., Pittsburgh, Pa.
Pierce Co., The Wm. B., Buffalo.
Roto Co., The, Hartford, Conn.

CLEANING COMPOUND.
Dearborn Chemical Co., Chicago, Ill.

COAL AND ASH-HANDLING MACHINERY.
Allen-Sherman-Hoff Co., The, Philadelphia, Pa.
Brady Conveyors Corp., Chicago.
Conveyors Corp. of America, Chicago, Ill.
Detrick Co., M. H., Chicago.
Fairbanks, Morse & Co, Chicago.
Hagan Co., George J., Pittsburgh.
Link-Belt Co., Chicago.
Stearns Conveyor Co., The, Cleveland, Ohio.
Stephens-Adamson Mfg. Co., Aurora, Ill.
Webster Mfg. Co., The, Chicago.
Weller Mfg. Co., Chicago, Ill.